ANÆSTHETICS

ANÆSTHETICS

AND THEIR

ADMINISTRATION

A TEXT-BOOK FOR MEDICAL AND DENTAL PRACTITIONERS AND STUDENTS

BY

FREDERIC W. HEWITT, M.A., M.D. CANTAB.

ANÆSTHETIST TO HIS MAJESTY THE KING; ANÆSTHETIST AND INSTRUCTOR IN ANÆSTHETICS AT THE LONDON HOSPITAL; LATE ANÆSTHETIST AT CHARING CROSS HOSPITAL AND AT THE DENTAL HOSPITAL OF LONDON

WITH ILLUSTRATIONS

London

MACMILLAN AND CO., LIMITED

NEW YORK: THE MACMILLAN COMPANY

1901

First Edition published elsewhere.
Second Edition, Revised and Enlarged, 1901.

PREFACE TO THE SECOND EDITION

In placing the second edition of this work before the profession, my first duty is to express my sincere thanks for the kindness and consideration with which the preceding edition was received. So greatly did this reception exceed my expectations, that it emboldened me to somewhat extend the original scope of the book, and to attempt a task which I had always felt myself incompetent to undertake—that of dealing with the history and experimental physiology of my subject. Hardly had I entered upon my new labours when the first edition became exhausted, and for upwards of two years, during which time the book has been out of print, I have been steadily devoting all my spare time to the production of the present volume, hoping to secure for it as favourable a reception as that accorded to its predecessor. But the work as it now stands is substantially a new one, and I therefore cannot help feeling some misgivings as to its future. Happily these are tempered by the reflection that in my endeavours to make the book as comprehensive and complete as possible I have been fortunate enough to obtain the assistance of numerous friends; and if I have any claim whatever to an indulgent hearing, this must be my chief plea. When I say that the MS. of the new chapters dealing with the experimental physiology of anæsthesia has passed through the hands of Dr. Leonard Hill, F.R.S., that Mr. Hugh Candy, B.Sc., F.C.S., has closely scrutinised all my chemical and chemico-physical statements, and that my colleague, Mr. H. Bellamy Gardner, in addition to kindly helping in many other directions, has spent much time in collecting and comparing all the available facts bearing upon the history of anæsthesia, it will be seen that the assistance I have received has been of

no mean order. I have striven, indeed, in this edition, to lay before the reader everything that is worthy of note in connection with the use and effects of general anæsthetics. It has been my aim to systematise the whole subject, so that information may be quickly obtained upon any chemical, physical, physiological, or clinical point. The interest which I personally take in the subject must be my excuse for having entered, in many places, into what may appear to be unnecessary detail. I have attempted to meet the requirements of the true student rather than those of men who are content to regard themselves, and to be regarded, as mere dispensers of drugs. It is an anomalous fact that the examining bodies have not as yet made instruction in anæsthetics a necessary part of the medical curriculum. When once this unsatisfactory state of things has been corrected, the importance of the subject will, I trust, be more generally recognised than it is at present.

FREDERIC W. HEWITT.

14 QUEEN ANNE STREET, CAVENDISH SQUARE, W.
January 1901.

PREFACE TO THE FIRST EDITION

THE following pages have been written in the hope that they may prove of service to those practitioners and students who wish to obtain information concerning the administration and effects of general anæsthetics.

Until within the last few years, systematic instruction in this branch of practice was almost unknown; and even at the present time the opportunities which a student has of making himself proficient in the use of anæsthetics are, with rare exceptions, lamentably inadequate. It thus happens that numerous recently qualified practitioners leave their hospitals possessing but the scantiest knowledge of the subject; and owing to the bewildering mass of literature which exists, and to the difficulty of extracting any really practical information from it, they regard all further attempts at self-instruction as hopeless, and resort to the simplest rather than to the safest plans of anæsthetising their patients.

My principal object, therefore, has been to present to the practitioner a clear and yet detailed description of the best methods of inducing and maintaining surgical anæsthesia in ordinary cases; to indicate what modifications in procedure should be resorted to on exceptional occasions; and to systematically consider the chief difficulties and dangers connected with general anæsthetics, and the proper manner in which they should be met. I have endeavoured, in fact, to make the book one to which reference may be made when any doubt exists as to the anæsthetic which should be given in any particular case. Supposing that a certain type of patient has to undergo a certain operation, and that the practitioner has not had much experience in the use of anæsthetics, it is

believed that he will find, by referring to these pages, practical hints which may materially assist him in the conduct of the case.

Another object which I have had in view has been to assist the student in acquiring that knowledge which is essential before he actually administers an anæsthetic for a surgical operation. I have tried, as far as possible, to give him the information of which he seems most in need, if I may judge by the questions which are most frequently put to me whilst engaged in instructing students in the operating theatres of the hospitals with which I am connected.

I may add that I commenced collecting materials for this work just ten years ago. During this period I have taken as accurate notes as possible of every case which has presented points of interest, and have made comparative trials of all the best known methods of producing anæsthesia. In this manner I have attempted to give a solid clinical foundation to every conclusion which I have ventured to put forward.

About a year before going to press I received from Dr. W. J. Sheppard of Putney the collection of Note-books left by his brother, the late Dr. C. E. Sheppard, one of the anæsthetists at the Middlesex Hospital and at the Guy's Hospital Dental School. These Note-books contain most carefully recorded notes of 2350 administrations. I felt that I could pay no better tribute to the memory of one whose friendship it was my privilege to enjoy, and whose loss so many must regret, than by going most thoroughly through these notes, and extracting what I considered to be most important. By the kind assistance and guidance of Dr. W. J. Sheppard, I have been able to bring together all the valuable observations made by his brother upon the pupil under chloroform, and upon many other points connected with the effects of anæsthetics: and I have incorporated these observations with my own.

In my endeavours to make this a clinical and practical treatise, I have thought it best to exclude much that might at first sight appear to be essential. Thus it will be found that only the more important general anæsthetics have been considered; that no detailed reference has been made to the discovery and history of the various means which have been

employed for the prevention of pain; and that no attempt has been made, either to discuss the action of anæsthetics from a purely experimental point of view, or to harmonise clinical and physiological facts. All these aspects of the subject, although of great interest *per se*, are beyond the aim of the present volume, and have therefore been omitted.

In conclusion, I am desirous of expressing my best thanks to Mr. Marmaduke Sheild and Mr. George Rowell for the very valuable assistance they have given me in passing the work through the press.

FREDERIC W. HEWITT.

10 George Street, Hanover Square, W.
July 1893.

KEY TO GENERAL ARRANGEMENT OF BOOK

Part I.—The History, Pharmacology, and Experimental Physiology of General Surgical Anæsthesia

CHAP. I.	CHAP. II.	CHAP. III.	CHAP. IV.
The evolution of general surgical anæsthesia.	The properties and impurities of the chief agents capable of producing general anæsthesia.	The theoretical and experimental physiology of general surgical anæsthesia.	The theoretical and experimental physiology of general surgical anæsthesia (*continued*)

Part II.—Preliminary Considerations before Anæsthetisation

CHAP. V.	CHAP. VI.	CHAP. VII.	CHAP. VIII.
The general principles to be observed in selecting anæsthetics and methods of administration.	Special considerations in the selection of anæsthetics and methods. (*a*) The state of the patient.	Special considerations in the selection of anæsthetics and methods (*continued*). (*b*) The nature of the operation, procedure, or condition for which anæsthesia is required.	The circumstances of the administration.

Part III.—The Administration

CHAP. IX.	CHAP. X.	CHAP. XI.	CHAP. XII.	CHAP. XIII.	CHAP. XIV.	CHAP. XV.
Nitrous oxide.	Ether.	Chloroform.	Bromide of ethyl, ethidene dichloride, amylene (pental), and other anæsthetics.	Anæsthetic Mixtures.	Anæsthetic sequences.	The use of morphine in conjunction with general anæsthetics.

Part IV.—The Management and Treatment of the Difficulties, Accidents, and Dangers of General Surgical Anæsthesia

CHAP. XVI.	CHAP. XVII.	CHAP. XVIII.
Minor difficulties.	The management and treatment of the difficulties, accidents, and dangers connected with respiration.	The management and treatment of the difficulties, accidents, and dangers connected with circulation.

Part V.—The Condition of the Patient after the Administration

CHAP. XIX

CONTENTS

PART I.—THE HISTORY, PHARMACOLOGY, AND EXPERIMENTAL PHYSIOLOGY OF GENERAL SURGICAL ANÆSTHESIA

CHAPTER I

THE EVOLUTION OF GENERAL SURGICAL ANÆSTHESIA

CHAPTER II

THE PROPERTIES AND IMPURITIES OF THE CHIEF AGENTS CAPABLE OF PRODUCING GENERAL ANÆSTHESIA

CHAPTER III

THE THEORETICAL AND EXPERIMENTAL PHYSIOLOGY OF GENERAL SURGICAL ANÆSTHESIA

CHAPTER IV

THE THEORETICAL AND EXPERIMENTAL PHYSIOLOGY OF GENERAL SURGICAL ANÆSTHESIA (*continued*)

PART II.—PRELIMINARY CONSIDERATIONS BEFORE ANÆSTHETISATION

CHAPTER V

THE GENERAL PRINCIPLES TO BE OBSERVED IN SELECTING ANÆSTHETICS AND METHODS OF ADMINISTRATION

CHAPTER VI

SPECIAL CONSIDERATIONS IN THE SELECTION OF ANÆSTHETICS AND METHODS: (*a*) THE STATE OF THE PATIENT

CHAPTER VII

SPECIAL CONSIDERATIONS IN THE SELECTION OF ANÆSTHETICS AND METHODS (*continued*): (*b*) THE NATURE OF THE OPERATION, PROCEDURE, OR CONDITION FOR WHICH ANÆSTHESIA IS REQUIRED

CHAPTER VIII

THE CIRCUMSTANCES OF THE ADMINISTRATION

PART III.—THE ADMINISTRATION

CHAPTER IX

NITROUS OXIDE

CHAPTER X

ETHER

CHAPTER XI

CHLOROFORM

CHAPTER XII

BROMIDE OF ETHYL, ETHIDENE DICHLORIDE, AMYLENE (PENTAL), AND OTHER ANÆSTHETICS

CHAPTER XIII

ANÆSTHETIC MIXTURES

CHAPTER XIV

ANÆSTHETIC SEQUENCES

CHAPTER XV

THE USE OF MORPHINE IN CONJUNCTION WITH GENERAL ANÆSTHETICS

PART IV.—THE MANAGEMENT AND TREATMENT OF THE DIFFICULTIES, ACCIDENTS, AND DANGERS OF GENERAL SURGICAL ANÆSTHESIA

CHAPTER XVI

MINOR DIFFICULTIES

CHAPTER XVII

THE MANAGEMENT AND TREATMENT OF THE DIFFICULTIES, ACCIDENTS, AND DANGERS CONNECTED WITH RESPIRATION

CHAPTER XVIII

THE MANAGEMENT AND TREATMENT OF THE DIFFICULTIES, ACCIDENTS, AND DANGERS CONNECTED WITH CIRCULATION

PART V.—THE CONDITION OF THE PATIENT AFTER THE ADMINISTRATION

CHAPTER XIX

THE AFTER-CONDITION OF THE PATIENT

ILLUSTRATIONS

PART I

THE HISTORY, PHARMACOLOGY, AND EXPERIMENTAL PHYSIOLOGY OF GENERAL SURGICAL ANÆSTHESIA

CHAPTER I

THE EVOLUTION OF GENERAL SURGICAL ANÆSTHESIA

It is quite impossible to say at what period in the world's history attempts were first made to prevent or relieve physical pain, nor can we do more than speculate with the uncertainty of ignorance as to the precise means which were first adopted for the mitigation of human suffering. That the ancient Egyptians, Assyrians, and Chinese were familiar with many vegetable substances capable of producing pleasurable, sedative, and anodyne effects[1] all writers upon this subject are agreed, and there can be no reasonable doubt that they took advantage of these effects when practising the rudimentary surgery of the time. The earliest record of the use of a nepenthe or narcotic is to be found in the following passage from Homer's *Odyssey*[2]:—

> Presently she (Helen) cast a drug into the wine whereof they drank, a drug to lull all pain and anger and bring forgetfulness of every sorrow. Whoso should drink a draught thereof, when it is mingled in the bowl, on that day he would let no tear fall down his cheeks, not though his mother and his father died, not though men slew his brother or dear son with the sword before his face, and his own eyes beheld it.

The Bible and the Talmud also contain references to the ancient practice of inducing torpor or deep sleep by artificial means; whilst Herodotus specially makes mention of the

[1] For additional information respecting the early history of anæsthesia I would refer the reader to those writers from whose works I have myself collected much valuable information, viz. *Chloroform and other Anæsthetics*, by John Snow, M.D., 1858; *Leçons sur les Anesthésiques et sur l'Asphyxie*, by Claude Bernard, 1875; *Artificial Anæsthesia and Anæsthetics*, by Henry M. Lyman, 1883; and *Les Anesthésiques*, by Dastre, 1890.

[2] *Odyssey*, iv. 220. Butcher and Lacy's translation.

custom of the Scythians of inhaling the fumes of a certain kind of hemp, the effect of which was to produce an exalted mental state followed by sleep.

The earliest allusion to the employment of narcotics for the relief of pain during surgical operations appears in the writings of Dioscorides,[1] who lived at the beginning of the Christian era. He refers to the practice of boiling in wine the root of the *Atropa Mandragora* and of administering a certain quantity of the decoction

before operations with the knife or actual cautery, that they may not be felt.

Pliny,[2] too, who was contemporary with Dioscorides, makes similar statements as to the powers of the mandrake, and in addition informs us that the seeds of the Rocket plant (*Eruca*) were sometimes infused in wine and taken by criminals about to undergo the lash in order to

produce a certain callousness or hardihood of feeling.

In the second century Galen[3] makes mention of the

power of mandragora to paralyse sensation and motion;

and about the same time Lucian,[4] a Grecian historian, had the following significant passage in his writings:—

He (Demosthenes) rouses his fellow-citizens, unwilling as if put to sleep by mandragora, employing his outspokenness as a sort of cutting and cauterisation of their apathy.

According to a French author,[5] there flourished in the third century a certain Chinese surgeon named Hoa-tho, who was in the habit of stupefying his patients, and possibly rendering them unconscious during surgical operations (incisions, acupuncture, amputations, etc.), by administering to them a preparation of hemp.

Coming to more recent times, we have evidence that in the thirteenth century of our era Hugo de Lucca, a Tuscan physician, prepared a certain oil with which he claimed

that by means of smelling alone he could put patients to sleep on occasions of painful operations;

[1] *De Med. Mat.* bk. iv. § 76.
[2] Lib. xxxv. cap. 94.
[3] Lib. vii. p. 207.
[4] *Demosthenes' Encomium*, p. 36.
[5] See *On Chloroform and other Anæsthetics*, by John Snow, M.D., p. 4.

but according to the testimony of Theodoric, his assistant, the vaunted preparation left much to be desired, for the patients had to be tied or held down by strong men. There can be no doubt, however, that it was the practice of many surgeons of the middle ages to produce some degree of stupefaction or insensibility during surgical operations, as is evident by the following extract from Du Bartas, a poet who lived in the middle of the sixteenth century:—

> Even as a surgeon minding off to cut
> Some cureless limb, before in use he put
> His violent engines on the vicious member,
> Bringeth his patient in a senseless slumber,
> And griefless then, guided by use and art
> To save the whole, cuts off the affected part.

In the year 1540, Valerius Cordus discovered sulphuric ether, but its narcotic properties were not recognised until three centuries later.

We are informed that in 1589 Giaubattista Porta, a surgeon who practised in Naples, used an essence made from hyoscyamus, solanum, poppy, and belladonna, enclosed in a leaden vessel, and

> the lid being opened, the patient would draw in by breathing the most subtle strength of the vapour, so that thereby he would be buried in a most profound sleep, nor be aware of what had been done to him.

Early in the seventeenth century, Shakespeare[1] makes Cornelius, a court physician, prescribe a drug which

> Will stupify and dull the sense awhile ;
> . . . but there is
> No danger in what show of death it makes,
> More than the locking-up the spirits a time,
> To be more fresh, reviving.

It was about this time that attempts were made in Italy, and particularly by Valverdi, to obtain unconsciousness by compression of the vessels of the neck—a procedure which is said to have been employed by the ancient Assyrians when circumcising children.[2]

In 1661 Greatrakes produced "magnetic sleep" by means of stroking and making passes over the patient's body. A

[1] *Cymbeline*, Act i. sc. 5.

[2] Claude Bernard, *op. cit.*

century later, in 1766, Anthony Mesmer evolved his theory of "animal magnetism" in a work on *The Influence of the Planets in the Cure of Disease.* After an almost equal lapse of time, James Braid of Manchester, in 1843, inaugurated the hypnotism of modern times by the publication of his treatise on *Neurypnology, or the Rationale of Nervous Sleep.*[1] And a few years later, whilst practising in India, Esdaile successfully induced hypnotic anæsthesia in a large number of native subjects, performing upon them a variety of surgical operations, many of which were, as the interesting records show,[2] of a serious and severe character. From time to time, since the days of Esdaile, hypnotism has been similarly applied; but as success is only attainable with certain subjects, and as there are numerous moral objections to the system, hypnotic anæsthesia is now generally regarded as possessing scientific interest rather than any real practical value.

It was not until the very close of the eighteenth century that our modern system of anæsthesia began to be foreshadowed. Up to this time the various means which had been adopted for the prevention of pain during surgical operations had been utterly unreliable—in other words, true anæsthesia, in the modern sense of the term, had never been attained. But the discovery of hydrogen by Cavendish (1766), of nitrogen by Rutherford (1772), of oxygen by Priestley (1774), and of nitrous oxide by the last-named observer (about the same date), marked the commencement of a new era in chemical physics, and paved the way for the introduction into medical practice of a new, precise, and reliable system of inducing the most complete unconsciousness, and of maintaining this state for any reasonable time without injurious consequences. The medical world gladly welcomed the idea of the therapeutic employment of vapours and gases. Thus in 1795 we find Dr. Pearson of Birmingham employing ether as an inhalation for the relief of asthma. In 1798 a "Pneumatic Institute" was inaugurated at Clifton by Dr. Beddoes, and in this Institute he proposed to treat phthisis and many other diseases by the

[1] See *Braid on Hypnotism.* New edition, 1899.

[2] *Natural and Mesmeric Clairvoyance, with the Practical Applications of Mesmerism in Surgery and Medicine,* by James Esdaile, M.D., 1852.

inhalation of gaseous and vaporised substances. Mr. (afterwards Sir) Humphry Davy was then Dr. Beddoes's assistant, and carefully studied the action of nitrous oxide. On one occasion, when suffering from the pain of cutting a wisdom tooth, he inhaled this gas, and found the pain was thereby considerably modified. In the year 1800 he wrote:—

> As nitrous oxide in its extensive operation appears capable of destroying physical pain, it may probably be used with advantage during surgical operations in which no great effusion of blood takes place.

Curiously enough, as we shall presently see, this important suggestion was not turned to practical account in surgery till nearly half a century later.

As the effects produced by different gases and vapours became more generally known, distinct points of similarity began to appear between nitrous oxide and ether. The exhilaration and hilarity produced by the former led to the term "laughing gas." In 1818 an article, believed to have been written by Faraday, appeared in the *English Quarterly Journal of Science and Arts,*[1] containing the following interesting passage:—

> When the vapour of ether mixed with common air is inhaled, it produces effects very similar to those occasioned by nitrous oxide. . . . It is necessary to use caution in making experiments of this kind. By the imprudent inspiration of ether a gentleman was thrown into a very lethargic state, which continued with occasional periods of intermission for more than thirty hours. . . .

It was not an uncommon event for lecturers upon scientific subjects to practically demonstrate the intoxicating properties of ether; and owing to the exhilarating and pleasurable sensations which the vapour produced, it became customary, particularly in certain country districts in the United States, for young people to engage in so-called "ether frolics." It is, indeed, to this latter circumstance that the discovery of surgical anæsthesia may be traced,[2] although it is difficult or impossible

[1] I am indebted to Lyman for this and other references.

[2] See an interesting pamphlet by Dr. Marion Sims, *The Discovery of Anæsthesia.* Dr. Sims and Dr. Lyman, who have carefully sifted the conflicting evidence in the controversy as to the discovery of anæsthesia, agree in their views, and it is surprising that more attention has not been paid to the facts which they have collected.

to decide to whom the chief credit of the discovery should be assigned.

There seems to be no reasonable doubt that in 1842 Dr. Crawford W. Long, a country practitioner, of Jefferson, Jackson County, Georgia, U.S.A., administered ether vapour with the distinct object and fortunate result of producing insensibility to pain during a surgical operation which he performed, and that he subsequently employed the same means with equal success. Long and his assistants had been in the habit of occasionally inhaling ether for amusement, and noticing that bruises had been unconsciously sustained not only by himself but by his assistants whilst in a state of ether intoxication, Long decided to test the anæsthetic effects of the vapour in surgical practice. He appears, however, to have taken no steps to make his important results known beyond the immediate circle in which he lived; indeed, it was not until some years later, when the rival claims of others were being hotly contested, that his own were brought forward and substantiated.

The next step in the evolution of anæsthesia took place in 1844, when Davy's predictions regarding the future of nitrous oxide in surgery became for the first time realised. In this year, Mr. Horace Wells, a dentist of Hartford, Conn., was present at a popular entertainment given by Mr. Colton, a lecturer on chemistry, and noticing, as Long had done in the case of ether, that one of the audience who had inhaled "laughing gas" had unconsciously sustained injuries whilst under its influence, he determined to test its merits as an anæsthetic in dentistry. He accordingly inhaled some of the gas, and a friend of his extracted a tooth for him without the slightest pain being experienced. The result was so marvellous that Wells immediately began to employ nitrous oxide in his own practice, and so convinced was he of the importance of his discovery that he soon gave a public demonstration in the surgical theatre of the Harvard Medical School. Owing, however, to the want of knowledge which necessarily prevailed as to the principles upon which the administration should be conducted, the demonstration proved a fiasco, and both Wells and his anæsthetic fell into undeserved discredit. For some

time, however, Wells continued to employ nitrous oxide in his practice, and with considerable success; but so keenly did he feel the contumely of his fellows and the failure of his hopes and schemes, that, on 14th January 1848, he destroyed his life. It is stated[1] that he opened a vein whilst in his bath, at the same time securing euthanasia by the inhalation of ether vapour.

The year 1846 is memorable as having witnessed the next step in the development of the subject, viz. the recognition and dissemination of the fact that by the inhalation of ether vapour complete surgical anæsthesia could be produced. In this year Mr. Wm. T. G. Morton, a former pupil and partner of Horace Wells, consulted the latter as to the manufacture of nitrous oxide. Wells referred Morton to a well-known chemist, Dr. Charles Jackson, who suggested that instead of employing nitrous oxide, Morton should try sulphuric ether, which was far easier to obtain. Acting upon Jackson's suggestion, and unaware of Long's results, Morton administered ether vapour in two or three dental cases, and with such success that he gave a public demonstration of his discovery in the General Hospital of Massachusetts on 17th October 1846, whilst Dr. Warren operated. This time the anæsthesia left little or nothing to be desired. It is regrettable that Morton tried to keep the nature of his anæsthetic a secret, securing a patent for it, and calling it by the name of "Letheon." Secrecy, however, was out of the question, owing to the characteristic odour of ether vapour; Dr. Bigelow soon discovered the nature of Morton's anæsthetic, and at once sent the news to London, from which centre it is needless to say it rapidly spread throughout the civilised world.

From these facts it will be seen that the credit of the discovery of surgical anæsthesia, in the modern sense of the term, can hardly be ascribed to any one individual. Long, Wells, Morton, and Jackson, of whom America may justly be proud, were one and all instrumental in the great work. Although it is true that Long took no steps towards enlightening and benefiting the world at large by the remarkable discovery he had made, and that had it not been for the

[1] Dastre, *op. cit.*

labour of his more enterprising countrymen, Wells and Morton, the blessings of anæsthesia might for many years have remained unknown, his well-conceived and fearless line of action deserves no small degree of admiration and respect. To Horace Wells belongs the honour of first intentionally producing surgical anæsthesia by means of nitrous oxide, and of attempting to establish by a public demonstration that system of inducing insensibility to pain which has since spread into all countries. And to Morton our thanks are due as being the first to introduce ether into surgical practice, and to make known the possibility of maintaining continuous anæsthesia during surgical operations. It is a remarkable and deplorable fact that, with the exception of Long, all these pioneers in the hitherto untrodden field of practical anæsthesia ended their days with symptoms of mental aberration or actual insanity. The legacy, however, which they left behind them has proved to be, and will for ever remain, of incalculable value to humanity.

The first operation performed in England under a general anæsthetic took place at the house of Dr. Boott in Gower Street, London, on 19th December 1846. Dr. Boott had received from Dr. Bigelow the news of the discovery of ether anæsthesia, and he communicated this news to Mr. Robinson, a neighbouring dentist, who, having devised an inhaler for the administration, extracted a tooth from a patient without inflicting the slightest pain. Two days later Mr. Squire administered ether to two patients at University College Hospital; Mr. Liston amputating a thigh in the one case and removing an in-growing toe-nail in the other. On the 19th of January 1847, Dr. (subsequently Sir) J. Y. Simpson employed ether for the first time in midwifery practice, and found that the pains of labour might be wholly abolished without interfering with uterine contractions.

On 8th March 1847, Flourens announced to the Académie des Sciences [1] that chloroform exerted on the lower animals an anæsthetic action analogous to that of ether; but little or no notice appears to have been taken of this observation. Later in the year, Dr. (afterwards Sir) J. Y. Simpson of Edinburgh, who had for some time been endeavouring to find a less

[1] *Comptes Rendus*, t. xxiv. p. 342, 1847.

irritating and more convenient anæsthetic than ether, happened to consult Mr. Waldie, a scientific chemist of Liverpool, who suggested that chloroform, one of the constituents of "chloric ether," which was then therapeutically employed as a carminative, and contained chloroform mixed in varying proportions with rectified spirit, might be tried with advantage. Curiously enough, attempts had already been made to induce anæsthesia by means of the vapour of "chloric ether"; but such attempts had, for obvious reasons, failed. Simpson soon satisfied himself that the vapour of chloroform, the more active ingredient of "chloric ether," was capable of producing anæsthesia, and he lost no time in benefiting others by the discovery he had thus made. On 10th November 1847 he read a paper entitled "Notice of a New Anæsthetic Agent as a Substitute for Ether in Surgery and Midwifery"; and as a result of this paper, and of Simpson's subsequent writings, chloroform rapidly began to supplant ether in general surgery. This is not surprising, for its vapour was more agreeable, it less frequently induced struggling and intoxication, its action was more speedy, and it was altogether more convenient and manageable. It was for a while believed to be absolutely safe, but the death of a young woman named Hannah Greener, on 28th January 1848, soon dispelled this idea. From time to time similar casualties occurred, and it soon became apparent that whatever might be the advantages of the new system of inducing insensibility to pain, the administration of chloroform was by no means without its grave risks to life. As death after death was reported, all kinds of theories were advanced to explain them. The most hopeless ignorance, however, prevailed, and several years passed by without any definite light being thrown upon the causation of these melancholy accidents.

The first attempts to place the administration of chloroform and ether upon a sound and scientific basis were made by Dr. John Snow, whose classical work *On Chloroform and other Anæsthetics* was published in 1858. Snow investigated the physical properties of the vapours of various anæsthetics; he performed a large number of experiments upon lower animals, with the object of determining the physiological effects which these agents produced; and he collected all the clinical and

experimental evidence which was then available, in order to ascertain the precise way in which death occurred under chloroform, ether, and other gaseous or volatile substances. He was the first to describe the effects produced by the inhalation of definite percentages of chloroform vapour and air. He came to the conclusion that, in the case of chloroform, fatalities usually arose from primary cardiac paralysis, due to the inhalation of too concentrated a vapour; and working on this assumption, he devised and used the first chloroform inhaler by which the percentage of vapour could be regulated. Subsequent research has tended to show that some primary interference with respiration is generally present in chloroform casualties, although there can be no doubt that chloroform is, as Snow maintained, a direct cardiac depressant. Among the substances investigated by Snow, special reference must be made to amylene—an anæsthetic which he was the first to administer, and one which he used in a considerable number of cases. The biography of Snow, written by his friend the late Sir B. W. Richardson, is full of interest, as showing the scientific enthusiasm with which Snow worked. To quote his biographer:

> His greatest deduction . . . and the proofs on which it is based, are to be found in his observations, where he explains that the action of the volatile narcotics is that of arresting or limiting those combinations between the oxygen of the arterial blood and the tissues of the body which are essential to sensation, volition, and all the animal functions. He demonstrated that these substances modify, and in large quantities arrest, the animal functions in the same way and by the same power as that by which they modify and arrest combustion, the slow oxidation of phosphorus and other kinds of oxidation unconnected with the living body when they (the narcotics) are mixed with atmospheric air.

By the death of Snow the advance of the subject suffered a distinct check. One of the results of his indefatigable labours was to direct attention to the hitherto unrecognised fact that by care and attention to detail deaths during anæsthesia could, to a very large extent, be avoided. Snow had not only shown himself to be an ardent seeker after truth, but a successful and skilful anæsthetist: not only had he investigated the subject from its scientific side, but he had silently demonstrated the importance of what may be called the personal factor in

anæsthetising. Of those who continued the work which he had begun there is no one to whom we are so much indebted as the late Mr. J. T. Clover, whose ingenuity and mechanical ability found such a happy sphere of activity in this department of practice. Snow's mantle, indeed, fell upon a successor who was conspicuously fitted to carry on the work which he had so ably begun. The first step taken by Clover was to perfect the principle of chloroform administration upon which Snow had laid such stress; and in 1862 he published an account of his chloroform inhaler, by which the administrator could adjust, more accurately than had hitherto been possible, the percentages of chloroform vapour and air. With this apparatus Clover anæsthetised a large number of patients, but not without becoming convinced that, so far as safety was concerned, chloroform was a less satisfactory anæsthetic than ether. He accordingly set himself to the task of rendering ether anæsthesia as practicable as that of chloroform, and, as we shall subsequently see, this task he most successfully accomplished.

The physiology of anæsthesia now began to attract attention not only in this country, but throughout the world. In 1864 a committee of the Royal Medical and Chirurgical Society, which had been appointed "to inquire into the uses and the physiological, therapeutical, and toxical effects of chloroform," issued an important Report (see p. 339). They agreed, in the main, with Snow's conclusions as to the danger of concentrated chloroform vapour, and strongly recommended as a substitute for this anæsthetic a certain mixture of alcohol, chloroform, and ether, which had been originally proposed and used by Dr. George Harley, and which has since been extensively employed under the name of the A.C.E. mixture. Elaborate investigations into numerous physiological questions were also made at about this time by Claude Bernard, Benjamin Richardson, and others.

In 1867 the last named of these observers introduced to the notice of the profession a new agent for producing general anæsthesia, to which he gave the name "bichloride of methylene"; and for some time this substance, which was considered to possess many advantages over chloroform, was favourably received by surgeons. For reasons, however, which will appear

in subsequent pages "bichloride of methylene" enjoyed but a brief reign.

In the same year, Dr. Junker described[1] his ingenious apparatus for administering chloroform—an apparatus which has proved to be of great value, more particularly in the surgery of the mouth, throat, and nose.

It was about this time that nitrous oxide began to regain the footing it had lost by Wells's untimely end and the failures which had attended his earlier administrations. Its revival is attributable to the energetic advocacy of Colton, the lecturer at whose demonstration Horace Wells had, about twenty years before, conceived the idea of painless tooth-extraction. In 1863 Colton formed an association in New York for the performance of dental operations under the influence of "laughing gas"; and the reports of his cases were so satisfactory that dentists began to give the matter their serious consideration. In 1864 Mr. Rymer, a London dentist, recorded several successful cases in which he had secured anæsthesia by means of nitrous oxide. It was not, however, till 1867, when Colton himself visited Paris and demonstrated before Dr. Evans, an English dentist practising in that capital, his methods of procedure, that the revived anæsthetic began to find widespread favour. On 31st March 1868 Evans came to England and gave a demonstration at the Dental Hospital of London (then in Soho Square); and on 7th December of the same year a joint committee of the Odontological Society and of the Dental Hospital issued a Report which was so favourable to nitrous oxide that from that time onwards this gas has occupied the foremost place amongst the anæsthetics of modern dentistry.

Twenty years had now passed since Simpson's discovery, and these had brought with them so many chloroform fatalities that many surgeons began to discard this anæsthetic and to return to ether. In the United States the latter had held its own from the first; but in all other parts of the world, and more particularly in its native country, chloroform had to a very large extent supplanted its predecessor. This is not

[1] *Medical Times and Gazette*, 30th November 1867, vol. ii. p. 590, and 1868, vol. i. p. 171.

surprising, for, as we have seen, it had many advantages over its rival. It had shown itself, however, to be distinctly more dangerous than ether, and this fact, together with the opportune discovery by Clover of the proper principles of ether administration, combined to strengthen the position of the latter. Clover pointed out the advantages of air-limitation during etherisation; he improved the methods for administering nitrous oxide; and he introduced the excellent system of using this gas as a preliminary to ether. In 1876 he published an account of his ingenious apparatus by which nitrous oxide or ether could be administered either separately or in succession; and in the following year he described his "portable regulating ether inhaler," which has since deservedly enjoyed a wider reputation than any other appliance of the kind. But the advances of ether were only partially successful in dethroning chloroform; for it soon became clear that, however safe ether might be, it was comparatively difficult to administer. A heated controversy as to the respective merits of the two anæsthetics now began. The advocates of ether urged that accidents from its use were rarely met with, and that when they occurred there was nearly always some pathological condition present, constituting an important factor in the case. The supporters of chloroform, on the other hand, alleged that deaths during its employment were often deaths from surgical shock rather than from the toxic effects of the drug; that, provided the respiration were closely watched and the pulse disregarded, chloroform was perfectly safe; and that although ether did not, like chloroform, kill its patient upon the table, it did so by its after-effects. In subsequent years this Ether *v.* Chloroform question lost much of its supposed importance; for experience has shown that both anæsthetics have their respective spheres of utility. Chloroform has, however, retained its position in most parts of Scotland, in tropical countries, upon the battlefield, and, in those practices in which portability and convenience have to be studied; whilst ether has steadily continued to gain ground, and is at the present moment the chief or routine anæsthetic in most surgical centres of the United Kingdom and in many other parts of the world.

The next point which occupied the attention of those interested in the progress of anæsthesia was the precise action of chloroform, and, more particularly, of lethal quantities of chloroform upon the mammalian organism. The first purely physiological research upon this subject was conducted by the "Glasgow" Committee of the British Medical Association, whose Report appeared in 1879. The Committee found that blood-pressure and cardiac action under chloroform were distinctly lowered, and whilst admitting that, in deaths from this anæsthetic, respiration generally ceased before cardiac action, they contended that the reverse might occur, that is to say, that the heart might be primarily paralysed. This view was in harmony with that advanced by Snow, but it was opposed to the principles laid down by Syme and the Edinburgh school. The famous Scotch surgeon had taught that chloroform never produced primary depression of the heart, and that, provided the respiration were carefully watched and the pulse disregarded, it was a perfectly safe anæsthetic.

In order that this disputed point might be settled, the Nizam of Hyderabad, at the suggestion of Surgeon-Major Lawrie, who had for many years strenuously upheld the teaching of Syme, very generously granted a sum of money for still further prosecuting scientific research, and, as the result, the First Hyderabad Chloroform Commission was appointed. Numerous experiments upon lower animals were made, and the conclusions at which the Commission arrived were in complete harmony with the teaching of the Edinburgh school. The medical profession, however, hesitated in accepting these conclusions, and it was accordingly proposed to institute a Second Commission to carry out further physiological experiments upon a large scale. The Nizam again most liberally aided the project by supplying funds, and Dr. Lauder Brunton, who had been nominated by the *Lancet*, left England for Hyderabad in order to take part in the work. The voluminous Report of this Commission appeared in 1891, and in all essential details it corroborated the conclusions at which the First Commission had arrived. Finality, however, had not yet been attained; for not only was it soon shown by eminent physiologists that there were numerous fallacies in

the technical work of the Commission, but that many of the tracings upon which criticism had been invited were capable of different interpretations from those assigned to them.

Amongst the numerous independent physiological researches which have been undertaken with the object of settling the chloroform question, mention must be made of the investigations of Bert, MacWilliam, Gaskell, Shore, and Leonard Hill. Bert's researches, which will be found described in subsequent pages, were in reality little more than a repetition of those conducted by Snow many years previously, and the results at which the French observer arrived were in the main identical with those of Snow. MacWilliam, Gaskell, Shore, and Leonard Hill have successfully accomplished the difficult task of harmonising the more important of the conflicting facts with which the subject was surrounded when they entered the controversial field. It has been conclusively shown by them, and may be accepted as proved, that when chloroform is administered to the full surgical degree, it undoubtedly acts as a cardiac depressant. In summing up the matter, therefore, it may be said that although there are some who still adhere to the Hyderabad doctrines, and regard chloroform as a drug which reduces arterial tension and depresses respiration, without interfering with cardiac action, the balance of present evidence is opposed to this view, and is in favour of the rival and more reasonable proposition, viz. that the fall of arterial tension which occurs is largely if not wholly due to a direct effect of the anæsthetic upon the heart substance; and that whilst it is perfectly true that respiration usually ceases before the heart fails, it is the effect of the anæsthetic upon the circulation, and not its influence upon the respiration, which is the characteristic and principal element in chloroform syncope. For further details on this point the reader is referred to Chap. IV.

Although a considerable amount of literary, scientific, and inventive energy has been expended in developing the practical side of anæsthesia, singularly few real advances have been made in this direction since the days of Clover. The most noteworthy is unquestionably the administration of oxygen with nitrous oxide gas—a plan which has totally changed the

character of nitrous oxide anæsthesia, and has given this anæsthetic a place in general surgery which it could not otherwise have secured. Another important advance has been the recognition of the clinical fact that during all forms of anæsthesia, but more particularly during the lighter degrees of this condition, there is a marked tendency for obstructed breathing to arise, and for the intercurrent asphyxial state thus induced to very seriously complicate the ordinary phenomena of anæsthetisation (see Chap. XVII.). The next most important addition to our store of knowledge has been a proper appreciation of the influence exerted by certain postures in modifying the symptoms of anæsthetised patients. And lastly, we now have at our disposal, in addition to the usual anæsthetics, so many mixtures and successions of these agents, and so many excellent methods of administration, that it is far easier than it formerly was to successfully treat those difficult and exceptional cases which must occasionally present themselves. The net result, therefore, is that provided the anæsthetist be thoroughly competent, anæsthesia may be induced and maintained with a minimum of discomfort to the patient, and with practically no risk to life.

Before closing this brief and imperfect sketch it may not be out of place to draw attention to the fact that during the half-century which has elapsed since the inception of painless surgery, very considerable and interesting changes have taken place in what may be termed the standard of anæsthesia. Four distinct phases or stages in the evolution of this branch of medical science may, in fact, be recognised. Thus (1) in Wells's and Morton's day the sole object of the administration was the simple prevention of pain during the surgical operation. It mattered not if the patient were to a certain extent unpleasantly conscious of his surroundings, and shouting, struggling, or other manifestations of what we now term imperfect anæsthesia were looked upon as a necessary part of the programme. Soon, however, (2) it began to be clear that anæsthetics might with safety be administered to such a degree that absolute unconsciousness not only of the operation itself, but of every incident connected with it, could be relied upon, and when the surgical operation was of such a nature that it

could not be performed under a single administration of the drug, the inhaler or handkerchief was reapplied. It was not thought advisable, however (as is obvious from Snow's writings), either to maintain anæsthesia for any great length of time or to keep up a very deep unconsciousness. Reflex movements and vocal sounds were, in fact, the rule rather than the exception; and surgeons cheerfully accepted the inconvenient accompaniments of this form of anæsthesia as more or less inevitable. (3) That deep and tranquil narcosis might be safely maintained, even for operations of long duration, now gradually began to be realised, and modern surgery is not a little indebted to this development, in that it has rendered possible of performance operations which would otherwise have been impracticable. Clover was the great pioneer in this direction. The next stage in the evolution of anæsthesia is the last to be chronicled. Until within quite recent years, the induction of unconsciousness was almost necessarily accompanied by inconvenient excitement. Now (4) it is possible, with rare exceptions, to prevent this initial intoxication, and to rapidly and safely plunge patients into the deepest anæsthesia.

CHAPTER II

THE PROPERTIES AND IMPURITIES OF THE CHIEF AGENTS CAPABLE OF PRODUCING GENERAL ANÆSTHESIA

A. NITROUS OXIDE

NITROGEN monoxide (otherwise known as protoxide of nitrogen, nitrous oxide, or "laughing gas") has a chemical formula of N_2O. It was first prepared by Priestley towards the close of the eighteenth century.[1]

Properties.—Under ordinary circumstances nitrous oxide is a colourless, transparent, feebly refractive gas, with a peculiar sweetish odour and taste. It can be respired without any discomfort when the apparatus for its administration is properly constructed. When pure it is wholly devoid of irritant properties, so that it is particularly useful in cases in which other anæsthetics excite cough, swallowing, etc. The gas has a sp. gr. of 1·52[2] (Colin). A litre of it weighs 1·97172 grm.; or 100 cubic inches 47·29 grains. Water at 0° C. dissolves a little more than its own volume, but the solubility diminishes as the temperature of the water is raised. Nitrous oxide was first liquefied by Faraday in 1823. Liquefaction takes place under a pressure of 30 atmospheres at 0° C., or 50 atmospheres at 7° C. Liquefied nitrous oxide is a colourless, very mobile body, having a sp. gr. of ·9369 at 0° C. (Andreef). Its boiling-point is stated by some observers to be − 87·9° C., under a pressure of 767·3 mm. of mercury; whilst others place it at − 92° C. The steel and iron cylinders

[1] Roscoe and Schorlemmer (*A Treatise on Chemistry*, 1884) give the date 1772; Watts (*A Dictionary of Chemistry*), 1776.

[2] 1·495 (Watts).

in which nitrous oxide is supplied by the manufacturers contain the agent in this liquid form. Roughly speaking, 15 oz. by weight of liquefied nitrous oxide will furnish 50 gallons of the gas. Solid nitrous oxide, in the form of compact snow, has been prepared by Wills,[1] who obtained it by a modification of Thilorier's method for preparing solid carbonic anhydride. The temperature of its freezing- or melting-point is stated to be $-99°$ C., as observed with an alcohol thermometer. As Dr. Sheppard pointed out,[2] the faulty working of nitrous oxide cylinders is often due to superficial solidification produced by the intense cold which results from the conversion of the liquid nitrous oxide into gas. Nitrous oxide is not easily decomposed, a considerable elevation of temperature being necessary to split it up into its constituent gases. But when a burning body is placed in the gas, the latter is decomposed, and combustion is supported.

Impurities.—The nitrous oxide supplied for anæsthetic purposes is usually free from impurities.[3] It is stated, however, that the gas has sometimes been found to contain **other oxides of nitrogen,** and **chlorine.** These gases would give the nitrous oxide an irritating odour and would induce coughing. The former impurities would be best detected by passing a slow stream of the nitrous oxide through a cold solution of ferrous sulphate acidulated with sulphuric acid; should the solution darken, the presence of other oxides of nitrogen would be indicated. Chlorine would be detected by its characteristic odour, and by its precipitating the chloride from a solution of argentic nitrate. Some writers state that "sulphates" may be present as impurities in nitrous oxide; but it is difficult to understand their existence in the gas.

Liquefied nitrous oxide may be preserved for an almost indefinite time in iron or steel cylinders. Some administrators[4] have drawn attention to differences between the gas obtained

[1] *Chemical Society's Journal*, II. xii. 21.

[2] See footnote, p. 210.

[3] Some years ago I had the nitrous oxide supplied to the Dental Hospital analysed by an eminent chemist. That obtained from one manufacturer was absolutely pure; that from another contained 1·2 per cent of oxygen.

[4] See *Brit. Journ. Dent. Science*, 15th Dec. 1884 ("Anæsthetics and their Administration," by J. W. Roberts, L.D.S.).

from liquid nitrous oxide and that which has never been subjected to liquefaction. Such differences probably depend upon the absence of all traces of atmospheric air in the nitrous oxide which issues from the cylinders. If the nitrous oxide be kept in a gaseous form, even for a few days, admixture with air will be liable to occur.

B. ETHER

Ethyl oxide (otherwise known as ethylic ether, vinous ether, sulphuric ether, or simply ether) has a chemical formula of $C_4H_{10}O$, or $(C_2H_5)_2O$. According to Watts[1] it was first prepared by Valerius Cordus in 1540, who gave it the name of "oleum vitrioli dulce."

Properties.—Ether is a transparent, colourless, very mobile, and highly volatile liquid, possessing a characteristic pungent odour and burning taste. It is perfectly neutral to test-paper. It refracts light strongly. The sp. gr. of pure ether is ·723 at 12·5° C. (Watts), or ·720 at 15·5° C. (Fownes). At 0° C. it is said to have a sp. gr. of ·7356 (Roscoe and Schorlemmer). According to Watts and Fownes it boils at 35·6° C. (96° F.) under the ordinary atmospheric pressure; but other observers (Kopp and Andrews) give the boiling-point at 34·9° C. Its vapour density, as compared to air, is 2·586 (Gay-Lussac), 2·565 (Snow); as compared to hydrogen, 37. Owing to its possessing such a high sp. gr., ether vapour may be poured from one vessel to another, and the process may be actually watched in bright sunlight. Olszewsky solidified ether, and found the melting-point to be −117° C. Ether is freely miscible with alcohol, chloroform, and almost all other hydrocarbon derivative compounds. It is also soluble to a certain extent in water, 1 part dissolving in 10 at 11° C. One part of water, moreover, dissolves in about 34 parts of ether. Ether vapour is highly inflammable, and when mixed with air detonates violently on the approach of a burning body. It burns with a white luminous flame. These facts should be borne in mind, not only when administering in the neighbourhood of an artificial light, but when pouring the liquid from

[1] Watts's *Dictionary of Chemistry* (new ed.), vol. ii. p. 464.

one bottle to another. Moreover, the actual cautery should never be used about the mouth or nose when the patient is under the full influence of ether.[1]

Impurities.—Pure ethylic ether should be perfectly neutral to test-paper, and should evaporate without leaving any residue whatever. Many samples of the best methylated ether leave a distinct and pungent residue (see p. 26). It should, moreover, form a clear mixture in all proportions with oil of copaiba. Ether containing **water** or **alcohol** forms an emulsion with considerable quantities of the oil (Watts). The presence of water may also be detected by means of potassium phosphate, which is insoluble in anhydrous ether, but dissolves partially in ether containing water, a brown residue being left.[2] Tannic acid, which is insoluble in ether but soluble in water, is also used as a test for the latter. Wet ether gives turbidity with carbon bisulphide, and the Pharmacopœia (1898) includes among the tests of Æther Purificatus the following: "It should dissolve in an equal volume of carbon bisulphide (absence of excess of water)." Alcohol is best detected by shaking the ether with water, which removes the alcohol; the aqueous extract is then gently warmed, a few crystals of iodine added, and then so much caustic potash that the solution just becomes colourless; after standing for a few hours, or at most a night, a bright yellow precipitate of iodoform will be thrown down, and the characteristic six-sided tablets or six-sided stellar groups may be examined microscopically.[3] By this test 1 part of alcohol in 2000 parts of water may be detected. The presence of **methylated ether** in pure ether is best detected by careful fractional distillation.[4] When ether

[1] Kappeler (*Anæsthetica*, p. 173) refers to a case at Lyons, in which, during the use of the cautery in the mouth, the ether vapour ignited. The face of the patient and the bag of the ether inhaler caught fire, and deep burns upon the face resulted. The case is also referred to in the *Brit. Med. Journ.* vol. ii., 1879, p. 826. Mr. Marmaduke Sheild records a similar case (*Proc. Med. Soc.*, 1887, vol. x. p. 144), and states that he has also known the expirations of a patient under ether to become ignited by an adjacent lamp. See also two cases reported in *Surgical Observations* by Dr. Warner.

[2] Romei, *Zeitschr. anal. Chem.*, 1869, p. 390.

[3] See Roscoe and Schorlemmer, vol. iii. part i. p. 318. See also Watts's *Dictionary of Chemistry*, 2nd Supplement, 1875, art. "Ethyl Oxide."

[4] Ether prepared from methylated spirit commences to boil at a lower temperature than ether prepared from rectified spirit. See an article by Mr.

has been preserved in an imperfectly stoppered bottle it is said to absorb oxygen, and to become acid from the presence of **acetic acid.** It is difficult, however, to understand this, for, owing to extreme volatility, the contents of the bottle would soon altogether disappear. Should acetic acid be present, the ether would, of course, redden blue litmus paper, and an aqueous extract of it would give the reactions for acetic acid. A dark red coloration with ferric chloride is not characteristic of the presence of acetic acid, as formates and other bodies give this reaction as well. Roscoe and Schorlemmer state that the most characteristic test is the conversion of acetic acid into cacodyl oxide: "For this purpose the acid is saturated with caustic potash, evaporated with a small quantity of powdered arsenic trioxide, and the mixture heated in a test-tube, when the characteristic smell is perceived." Should the aqueous extract contain **sulphuric acid**, it may be detected by the white precipitate (insoluble in hydrochloric acid), which it gives with baric chloride. The Pharmacopœia (1898) includes among the tests to which "purified ether" must conform the following: "On shaking with half its bulk of a dilute solution of potassium bichromate acidulated with sulphuric acid, and setting aside, the supernatant ether should have no blue colour (absence of hydrogen peroxide)." This apparently supersedes the starch test of the older editions, and indicates the official conclusion of the vexed questions to which that test gave rise.[1]

H. W. Jones, F.C.S., on "The Detection of Methylated Ether" (*Pharm. Journ. and Trans.* vol. xvi., 1885-86, p. 663). It is stated that as little as 10 per cent of methylated ether can thus be found. By removing the distillate immediately the thermometer indicated 90° F., the following results were obtained:—

100 c.c. of each taken.	C.c. obtained.	Remarks.
Rectified ether, sp. gr. ·720 . .	0	
Rectified ether, sp. gr. ·730 . .	0	
Methylated ether, sp. gr. ·717 .	60	Boiled freely at 74° F.
Methylated ether, sp. gr. ·720 .	54	
Methylated ether, sp. gr. ·730 .	23	
Rectified (·735) and methylated (·730) in equal parts	7	After cooling and again heating, a further 5 c.c. obtained.

[1] Prof. Dunstan and Mr. Dymond came to the conclusion that impure ether sometimes contains hydrogen peroxide, though they failed to produce it in pure ether by the prolonged action of oxygen.

Professor Ramsay, in an article which appeared in the *Nineteenth Century* for April 1898, is inclined to attribute the peroxide reactions sometimes given by ether to a peroxide of ethyl. It is perhaps a matter rather of theoretical interest than of practical importance, whether the effects should be attributed to hydrogen peroxide or to ethyl peroxide. In either case the effects due to the peroxide may be obviated by adopting the simple expedient of putting some clean mercury in the ether bottle as suggested by Professor Ramsay in the same article. The mercury becomes oxidised at the expense of the peroxide which is thus decomposed, and, as no injurious volatile by-products are formed by the change, the suggestion seems as satisfactory as it is simple.

According to Martindale,[1] the following kinds of ether are obtainable:—

(1) *From Pure Rectified Spirit*

(i.) *Æther* (Off.). Sp. gr. ·735. Ordinary medicinal ether. Contains a little spirit and water. Not so suitable for inhalation as—

(ii.) *Æther Purificatus* (Off.). Sp. gr. not exceeding ·722, and not below ·720.[2]

(2) *From Methylated Spirit*

(i.) *Absolute Ether—Methylated.* Sp. gr. ·717–·719. Contains a little methylic ether, and is specially adapted for producing local anæsthesia, as it boils under 80°. Not adapted for producing general anæsthesia.

(ii.) *Rectified Ether.* From methylated spirit. Sp. gr. ·720. Well washed to free it from methylic ether, purified, and re-distilled. Well adapted for producing general anæsthesia.

(iii.) *Methylated Ether.* Sp. gr. ·730. For common purposes.

Putting on one side the first and third of the methylated ethers in the above list, which are used either for producing local anæsthesia or for common purposes, and which should never be employed for inhalation,[3] and putting on one side also the ether standing first of all on the list, which is rarely used for inhalation, we are left with "Æther Purificatus" of

[1] *Extra Pharmacopœia*, 1892.

[2] I am informed by Messrs. Robbins and Co. that the sp. gr. of their "anhydrous ether," which I have found to answer well, is ·720, or is even a little below this, and that its boiling-point is as near as possible 95° F.

[3] A fatal result has been known to follow the administration of "local anæsthetic ether" (see *Lancet*, 7th August 1875). These impure ethers, when inhaled, produce much irritation, respiratory difficulty, cough, salivation, etc.

the British Pharmacopœia, 1898, and "rectified ether from methylated spirit," or, as it is sometimes termed, "pure methylated ether." Opinions are still divided as to the relative merits of these two ethers. There are some who prefer the "pure methylated ether" to that obtained from rectified spirit; there are others who hold exactly opposite views; and there are others again who state that they can detect no difference in the effects of the two varieties. I have for several years past administered both kinds of ether, with the object of carefully comparing the effects. I have often given the purer ether on one occasion and the methylated ether on another to the same patient, and have noted the results. I have also given the ethers alternately during a prolonged administration, and have watched the effects produced. My experience leads me to the conclusion that the purer ether is preferable. It produces less irritation, less mucus, less respiratory difficulty, and less after-nausea and vomiting than the best methylated brands. The vapour of pure ether, moreover, is less disagreeable than that of methylated ether. The so-called "pure methylated ether," which is, to my knowledge, very largely used at several of our hospitals, commences to boil at such a low temperature that in the summer time the heat of the hand is often sufficient to induce ebullition, methylic ether in a gaseous form apparently being evolved. This low boiling-point of "pure methylated ether" has led many to infer that recovery from etherisation should take place more rapidly than after the use of ether prepared from rectified spirit. But this is questionable. There are impurities in most if not in all of the methylated ethers; and these remain behind, as it were, either in the inhaler or in the patient. The precise nature of such impurities is at present unknown. I have myself evaporated considerable quantities of "pure methylated ether," and can corroborate Professor Dunstan's statement that a disagreeably smelling residue remains. Possibly **fusel oil** may be present in this residue. After a long administration of methylated ether some of this impurity must be inhaled by the patient. It is stated indeed by those who prefer methylated ether to the purer drug that patients remain longer under its influence than when ether prepared from rectified spirit has

been used; and they urge that this is an advantage. It is, however, in my experience, the reverse of advantageous. A good and quick recovery from the effects of ether is to be encouraged, and such a recovery is to be looked for when the purest ether has been used. The comparatively tardy recovery from methylated ether (I am speaking of long administrations) is probably connected with the inhalation of impurities which are not found in Æther Purificatus.

C. CHLOROFORM

Trichlormethane, dichlorinated chloride of methyl, perchloride of formyl, commonly known as chloroform, has a chemical formula of $CHCl_3$. Liebig, Soubeiran, and Guthrie appear to have independently discovered chloroform[1] in the year 1831; but its real chemical composition was not ascertained till 1834, when Dumas[2] determined its true formula.

Properties.—Chloroform is a colourless, transparent, mobile, and volatile liquid, possessing a pleasant, penetrating odour, and sweet fiery taste. Its sp. gr. at 17° C. is 1·491 (Regnault); at 0° C. 1·52523 (Pierre). Chloroform obtained by crystallisation at an extremely low temperature (Pictet's process) is stated to have a sp. gr. of 1·5002 at 15° C.[3] The boiling-point of pure chloroform, according to Regnault,[4] is 60·16° C. (140·2° F.); according to Liebig, 61° C. (141·8° F.). Pierre states that chloroform boils at 63·5° C., with the barometer at 772·52 mm. of mercury. Its vapour density as compared to air is, according to Dumas, 4·199; according

[1] According to Roscoe and Schorlemmer, chloroform was discovered in 1831 by Liebig (*Pogg. Ann.* xxiii. 444; *Ann. Pharm.* i. 31, 198), and about the same time, but independently, by Soubeiran (*Ann. Chim. Phys.* [2], xlviii. 131; *Ann. Pharm.* i. 272). The former considered it to be a chloride of carbon; the latter gave it the name "éther bichlorique." According to Watts (*Dictionary of Chemistry*), Liebig's discovery was in 1832; but as Liebig strongly put forward his claims to priority (*Ann. Chem. Pharm.* clxii. 161) it seems certain that, so far as he and Soubeiran were concerned, the discovery was almost simultaneous. Dr. Buxton (*Anæsthetics*, 2nd ed. p. 94) supports the claims of Samuel Guthrie, of Brimfield, Massachusetts.

[2] *Ann. Chim. Phys.* lvi. 115; *Ann. Pharm.* xvi. 164.

[3] Martindale's *Extra Pharmacopœia*.

[4] *Jahresb.*, 1863, p. 70.

to Regnault, 4·230. If the density of hydrogen be taken as 1, that of chloroform vapour is 59·75. Chloroform remains liquid and transparent at – 16° C. (Pierre), but may be solidified by the cold produced by its own evaporation. Snow found that chloroform dissolves in about 288 times its volume of water. It is miscible in all proportions with alcohol, ether, and other organic liquids. It is not inflammable, but its vapour is decomposed when passed into a lighted spirit-lamp, and burns with a smoky flame, emitting fumes of hydrochloric acid.

The following extracts from the writings of Snow may here be conveniently introduced :—

There are three drops to a grain of the liquid, and as a minim of it weighs a grain and a half, there are nine drops in two minims. . . . One grain of chloroform produces 0·767 of a cubic inch of vapour at 60° F. when its sp. gr. is 4·2. . . . Serum of blood at 100°, and at the ordinary pressure of the atmosphere, will dissolve about its own volume of vapour of chloroform. . . . Under ordinary circumstances the vapour of chloroform has, of course, no separate existence, but is always mixed with air. It can exist in a pure state only when the temperature is raised to 140° or upwards, or when the pressure of the atmosphere is in a great measure removed by the air-pump. The quantity of vapour of chloroform that the air will hold in solution at different temperatures, under the ordinary pressure of the atmosphere, depends on the elastic force of the vapour of these atmospheres. It is governed by a law precisely analogous to that which determines the amount of watery vapour which air will hold in solution.

The following table shows the result of experiments I made to determine the quantity of vapour of chloroform that 100 cubic inches of air will take up, and retain in solution at various temperatures :—

Temperature Fahrenheit.	Cubic Inches.	Temperature Fahrenheit.	Cubic Inches.
Degrees.		Degrees.	
40	7	70	24
45	8	75	29
50	9	80	36
55	11	85	44
60	14	90	55
65	19		

In the above table, the air is a constant quantity of 100 cubic inches which becomes expanded to 107, and so on ; but it may be convenient to be able to view at a glance the quantity of vapour in 100 cubic inches of the saturated mixture of vapour and air, at different temperatures, and in the table which follows the figures are so arranged as to show this :—

Temperature Fahrenheit.	Air.	Vapour.
Degrees.		
40	94	6
45	93	7
50	92	8
55	90	10
60	88	12
65	85	15
70	81	19
75	78	22
80	74	26
85	70	30
90	65	35

Chloroform is found to be less liable to decomposition when a very small percentage of ethylic alcohol is added to it.[1] The chloroform of the British Pharmacopœia (1898) therefore contains sufficient absolute alcohol to produce a liquid having a specific gravity not less than 1·490, and not more than 1·495. Should alcohol be present to a greater extent than this the sp. gr. would, of course, be lower. It is stated that the chemically pure chloroform obtained by Pictet's freezing process does not require this addition of alcohol in order to preserve it;[2] but further research is necessary on this point.

Impurities.—A great deal of discussion has from time to time taken place concerning the nature of the impurities of chloroform, and the possibility of such impurities having been responsible in some cases for the supervention of dangerous or fatal symptoms during chloroformisation. Whilst impurities and decomposition products have undoubtedly been found in chloroform which has produced dangerous symptoms, such symptoms have often appeared under the influence of chloroform which has stood with credit the recognised tests of purity. In the present unsettled state of the subject it will therefore be best that we should confine ourselves to facts, and avoid all inferences as far as possible.

[1] Mr. David Brown Dott, writing on "The Purity of Chloroform for Anæsthetic Purposes" (*Pharm. Journ. and Trans.*, 1882, p. 769), states that one-tenth per cent of alcohol is sufficient.

[2] *Lancet*, 19th Dec. 1891: "On a New Method of Purifying Chloroform," by Réné du Bois-Reymond.

The chloroform used for anæsthetic purposes should conform to the following tests:—

1. It should possess a sp. gr. and boiling-point[1] such as have been already mentioned.

2. It should be perfectly transparent and colourless.

3. It should be absolutely neutral to test-paper.

4. It should possess an agreeable, bland, and non-irritating odour.

5. When a portion is allowed to evaporate spontaneously from a watch-glass it should leave no residue, either of water or of any substance possessing a strong smell.[2]

6. When shaken with concentrated sulphuric acid no brownish coloration, or only the faintest, should result.

7. It should form no precipitate with a solution of argentic nitrate.

8. It should not acquire a brown colour when heated to the boiling-point with caustic potash.

Other tests of purity have been suggested. Several years ago M. Yvon drew attention[3] to the fact that an alkaline permanganate solution, when added to impure chloroform, is changed from violet to green, whereas the violet colour is retained when the chloroform is pure. But subsequent experience has shown[4] that the small quantity of alcohol which is usually added to chloroform is quite sufficient to change the colour of the permanganate, so that Yvon's test can hardly be depended upon.

[1] Chloroform may be contaminated with substances possessing a higher or lower boiling-point than the chloroform itself. Thus Prof. Mentin of Warsaw (*Pharm. Journ. and Trans.*, 1888-89, p. 991) found, on taking 49 c.c. of a sample of chloroform which was obtained from a "respectable German house," that 6·5 c.c. came over at 59°–60° C., 30 c.c. from 60°–61°, and 12·5 c.c. above 61°. Other investigators have recorded similar results.

[2] Impure chloroform may leave a distinct residue when evaporated. For example, the residue of the sample referred to in the last footnote weighed ·002 grm., and consisted of well-defined acicular crystals surrounded by a yellowish liquid. It had a most disagreeable odour of nitro-benzol and tobacco, and when inhaled produced giddiness and headache. After forty-eight hours the smell was replaced by that of benzoic acid. When the residue was heated on a watch-glass and partly evaporated, the remainder turned brown and evolved a smell like that of burnt indiarubber. The chloroform from which this residue was obtained had caused alarming symptoms in one-half of the cases in which it had been employed.

[3] *Pharm. Journ. and Trans.*, 1882, p. 711.

[4] *Ibid.*, 1882, pp. 740-769.

Now that there are several reliable manufacturers of chloroform for anæsthetic purposes, the difficulty of obtaining a pure drug is far less than it formerly was. But the purest chloroform is liable to decomposition. As has been shown by Professor W. Ramsay,[1] exposure to sunlight and air will, in the course of a short time, lead to the formation of carbonyl chloride. Professor Ramsay states that he has found this substance in many specimens of chloroform submitted to him for analysis, and that it may be detected, on adding baryta solution to the chloroform, by a white film making its appearance at the junction of the two liquids. In the article to which reference has already been made (p. 25), he suggests keeping a little slaked lime in the chloroform bottle, so that should any carbonyl chloride form, it may be converted into harmless chalk and chloride of calcium. Hydrochloric acid would, if present, be also removed by the lime. This acid and free chlorine have for several years been known to be present in chloroform which has undergone decomposition, and are to be detected by the chloroform reddening blue litmus paper, forming a precipitate with argentic nitrate, and liberating iodine from a solution of potassium iodide. **Acetic acid** (to be detected by the process described on p. 24), **formic acid**, and **aldehyde** are also stated by Kappeler to be produced by the decomposition of chloroform. The detection of **alcohol** is best effected by making a watery extract of the chloroform, and obtaining the iodoform reaction (p. 23). According to Kappeler, alcohol may also be conveniently recognised by the turbidity which results when equal parts of oil of almonds and chloroform are shaken together, or by the coagulation which takes place in white of egg when a few drops of the chloroform are added, or by the milky appearance which drops of chloroform assume when allowed to fall through distilled water.[2] When alcohol is present in excess of that quantity which is customarily added, the sp. gr. of the chloroform will, as already mentioned, be lower than 1·49. Alcohol, as well as other easily oxidisable substances, will, if present in chloroform, cause a cold solution

[1] See *Lancet*, 23rd January 1897, p. 240. Dr. Newman and Professor Ramsay believe that they have traced the supervention of dangerous symptoms and after-sickness to impure chloroform.

[2] Kappeler, *op. cit.*

of potassium bichromate acidulated with dilute sulphuric acid to turn green. Should **ether** be present it would, like alcohol, lower the sp. gr. of the chloroform. It may, moreover, be detected by dropping a watery solution of iodine into the chloroform. Should the drops remain of an amethyst colour and transparent, the chloroform is pure, but should the drops assume a dark red colour, ether is present. Crystals of nitro-sodic sulphide of iron are insoluble in pure chloroform, but dissolve in the presence of ether or alcohol. Should **methyl compounds** be present they may be detected by the chloroform becoming dark-coloured or black when treated with concentrated sulphuric acid, or by a black oily layer forming when the chloroform is treated with chloride of zinc (Kappeler). According to Roussin,[1] pure chloroform shaken with di-nitro-sulphide of iron remains colourless; but if it contain alcohol, ether, or wood spirit, it will acquire a dark colour. Kappeler,[2] referring to this test, also states that the reaction is not only caused by the presence of ethylic alcohol and ether, but by aldehyde and amylic alcohol. According to Roscoe and Schorlemmer, pure chloroform does not attack bright metallic sodium, even at the boiling-point. Should the metal become coated with a white coating of chloride, the presence of chlorine compounds, such as **dichlorethane** or **ethylene dichloride,** may be presumed. As a corroborative test of the presence of these impurities, these authors state that the chloroform when heated with alcoholic potash evolves the combustible gas ethylene. In one of the 101 fatal chloroform administrations collected by Kappeler, **allyl chloride** was discovered in the chloroform, but the same chloroform had been used without bad effects in other cases. In another of these cases "higher combinations of chlorine" were found in the chloroform. But in nine of the fatal cases in which the chloroform used was examined no impurity was detected.

Quite recently Professor Pictet has introduced a method of purifying chloroform by crystallisation. The chloroform is first subjected to a moderate degree of cold, in order to remove water and other easily crystallisable bodies. Intense cold is

[1] Watts's *Dictionary of Chemistry*: "Chloroform."
[2] *Op. cit.*

then applied and the chloroform crystallises, leaving a mother-liquor which is stated to retain any impurities that may have been present. The crystallised chloroform is then allowed to liquefy.[1]

Chloroform should always be kept in a cool, dark place, and in accurately stoppered bottles. As it is now an established fact that exposure to light and air is liable to set up decomposition, chloroform should certainly be obtained in small rather than large bottles, in order to lessen the chances of such decomposition taking place.

This is perhaps the most appropriate place in which to draw attention to the interesting fact that chloroform vapour is **decomposed by contact with a naked flame**, phosgene and hydrochloric acid gases being formed, and the phosgene again splitting up, as indicated by the following equations: $2CHCl_3 + O_2 = 2COCl_2 + 2HCl$; and $COCl_2 + H_2O = 2HCl + CO_2$. When chloroform is administered in a small, badly-ventilated room, in which there is an oil or gas stove for heating purposes, or gas burners or oil lamps for illuminating purposes, all occupants of the room, including the patient, will be liable to be affected by the irritant products of decomposition. Smarting of the eyes, burning sensations about the upper air-passages, dry spasmodic cough, and a feeling of oppression and tightness about the chest, may be experienced by those engaged in the operation. The smaller the room, the greater the number of naked flames, and the longer the administration, the more marked will be the symptoms. I have myself frequently experienced these sensations in a minor degree; and, curiously enough, have sometimes found the pungent odour more noticeable on leaving the room in which the operation has been performed than in the room itself. It has occasionally happened that the occupants of a room, including the patient, have been affected by persistent bronchial irritation, bronchitis, and even broncho-pneumonia after exposure to the fumes of the decomposed chloroform; and cases have been recorded in which the patient has, in the

[1] See *Lancet*, 19th December 1891, p. 1415, and *Brit. Med. Journ.*, 23rd January 1892, p. 209. In the latter journal, Dr. René du Bois-Reymond gives an account of "the toxic action of impure chloroform."

course of the administration, displayed such asphyxial symptoms as to render remedial measures necessary.[1]

D. ETHYL BROMIDE

Ethyl bromide, bromide of ethyl, hydrobromic or bromhydric ether, C_2H_5Br, was first prepared by Serullas in 1827. It is a transparent, colourless, highly volatile liquid, of a strong sweetish ethereal odour and pungent taste. It has a sp. gr. of 1·4189 at 15° C. (Mendelejeff), and of 1·4733 at 0° C. (Pierre). Its vapour density, according to Marchand, is 3·754. It boils at 40·7° C., when the barometer stands at 757 mm. (Pierre). It is sparingly soluble in water, but mixes in all proportions with alcohol and ether. It burns, when ignited, with a green smokeless flame, bromine vapour being evolved. When exposed for some time to air, ethyl bromide decomposes and bromine is liberated.

According to Merck, ethyl bromide should stand the following tests: (1) when put on the hand it must evaporate quickly and absolutely, without residue, producing a marked feeling of cold; (2) the filtration with water should be neutral and should not change on the addition of nitrate of silver; (3) the addition of concentrated sulphuric acid should cause no discoloration.[2]

E. ETHIDENE DICHLORIDE

Ethylidene chloride, dichlorethane, or, as it is more commonly called, ethidene dichloride, was discovered by

[1] It is difficult to say who first drew attention to the decomposition of chloroform by naked flame. The earliest reference I can find is in the *China Medical Missionary Journal* for December 1888, p. 160; but the anonymous writer of the short article therein refers to observations on the subject by "a contributor to a prominent medical journal." Iterson, Fischer, and Zweifel drew attention to the phenomenon in 1889; and in that year an article by Dr. Patterson, containing interesting personal experiences, appeared in the *Practitioner*, vol. xlii. p. 418. Zweifel reported a fatal case of bronchitis and pneumonia. See also *Lancet*, 12th March 1898, containing an interesting letter from Dr. J. J. Waddelow. See also *Birmingham Medical Review*, August 1892, containing an article by Dr. Charles Martin. The subject has attracted much attention on the Continent. According to Bréaudat (*Dict. de Physiologie*), the combustion of chloroform vapour gives rise to hydrochloric acid, and an acrid and acid oil containing several organic bodies; but he failed to find any $COCl_2$.

[2] In the second test, *washing* with water is probably meant, *i.e.* the washings should be neutral, etc.

Regnault, who, from the mode of its preparation, gave it the name of monochlorinated chloride of ethyl. Snow was the first to use ethidene dichloride as a general anæsthetic.[1] It has a chemical formula of $CH_3 . CHCl_2$, and is a metamer of ethylene dichloride, or Dutch liquid. Ethidene dichloride is a transparent colourless liquid, resembling chloroform in taste and odour. According to Watts, its sp. gr. is 1·189 at 4·3° C. (Geuther); according to Roscoe and Schorlemmer, 1·2044 at 0° C. (Thorpe). The boiling-point of the purest samples has been found to be 60° C. (Beilstein and Krämer), four degrees lower than the boiling-point of the substance originally prepared and studied by Regnault. The vapour density of ethylidene chloride is 49·54.[2] It is distinguished from ethylene dichloride by its boiling-point (ethylene dichloride boiling between 83° C. and 84° C.) and by its behaviour with cold alcoholic potash, which decomposes Dutch liquid but has little or no effect upon ethylidene chloride. It is soluble in alcohol and ether, but is insoluble in water.

Clover found[3] that the ethidene dichloride supplied for anæsthetic purposes had not a uniform boiling-point, but could be divided, by fractional distillation, into two or more substances. That which he used had a sp. gr. of "1225," and a boiling-point of 46·1°, the temperature rising to 60°, at which point it boiled steadily till it was nearly all dissipated.

F. AMYLENE. PENTAL

Amylene, C_5H_{10}, was discovered by Balard in 1844, and first used as an anæsthetic by Snow. According to the latter authority, whose views have since been endorsed by all leading chemists, amylene is not a very definite compound, but a mixture of several isomeric bodies.[4]

Amylene is a colourless, thin, and very volatile liquid. Although not pungent when inhaled, its vapour has a dis-

[1] The reader is referred to Snow's interesting article on "Monochlorurretted Chloride of Ethyle" (*sic*), *op. cit.* p. 420.

[2] For further information see Watts's *Dictionary of Chemistry*, vol. vii. 2nd Supp. 1875, p. 490.

[3] *Brit. Med. Journ.*, 29th May 1880, p. 797.

[4] See Roscoe and Schorlemmer, vol. iii. pp. 240 and 283. Also Watts's *Dictionary of Chemistry*, 3rd Supp. vol. viii. pt. i. 1879, p. 79.

agreeable odour, somewhat resembling that of wood spirit. The liquid is almost without taste. The sp. gr. of amylene is stated to be ·66277 at 0° C., or ·6544 at 10° C. (Watts).[1] The sp. gr. of the amylene used by Snow was ·659 at 56° F. The boiling-point of amylene differs in different samples, and is not constant in the same sample. Balard placed it at 39° C., Frankland at 35° C., and Kékulé at 42° C. The vapour of amylene is inflammable.

At about the time of Snow's death, Duroy is said[2] to have carefully studied the boiling-point of amylene, and to have found that it varied widely—from 30° C. to 62° C. He found, moreover, that pure iso-amylene had a constant boiling-point of 38° C. (according to other observers, 35°). The name "pental" is applied to a pure form of amylene introduced into commerce by Mering, and now used, more especially by dental surgeons, in Germany.

[1] See *Ann. Ch. Pharm.* 4th Supp. 143.

[2] See *Brit. Journ. Dent. Science*, 1st June 1892, in which an abstract of a paper on "Pental" from the *Vierteljahrsschrift für Zahnheilkunde* appears. The paper is by Dr. Julius Kossa and Herm. Neumann of Budapest.

CHAPTER III

THE THEORETICAL AND EXPERIMENTAL PHYSIOLOGY OF GENERAL SURGICAL ANÆSTHESIA

INTRODUCTORY

THE agents whose chemical and physical properties have just been considered constitute the more important members of the therapeutic group known as **general anæsthetics.** The remaining members of this group are comparatively unimportant, for they are, so far as our present knowledge goes, incapable of producing such satisfactory effects as those obtainable by nitrous oxide, ether, chloroform, and the other substances to which reference has been made. Considerable differences of opinion exist as to the agents which should or should not be thus grouped together; and the question naturally presents itself: What is a general anæsthetic? To say that it is a substance which has the power of destroying conscious sensibility throughout the organism is hardly sufficient; for such a definition would include many therapeutic bodies which possess, so to speak, merely incidental anæsthetic properties, and which are more fitly included under other groups, such as narcotics, soporifics, anodynes, convulsants, etc. According to our present conceptions a general anæsthetic must possess the following properties:—

(*a*) It must be able to produce universal insensibility;

(*b*) It must be capable of being readily introduced into the circulation without discomfort to the patient;

(*c*) It must produce its effects gradually and progressively, so that its action may be under control;

(*d*) It must bring about not only general sensory paralysis, but such a loss of motor power as to render practicable the performance of surgical operations;

(*e*) Its action upon the sensory and motor systems must not be associated with greater excitement, greater convulsive movement, or greater interference with respiration, circulation, or other important vital processes than can be controlled or corrected by the anæsthetist;

(*f*) And lastly, it is essential that the agent employed shall be of such a kind that when it is withdrawn the whole organism will resume its functions, and return to that condition in which it existed when the anæsthetic was first applied.

All agents fulfilling these requirements may be allowed a place in the group of general anæsthetics; and the more completely any agent fulfils such requirements the higher will be its place in the group. Anæsthetics such as nitrous oxide, ether, and chloroform thus occupy high positions; whilst others, such as amylene, nitrogen, etc., have but a questionable right to be included in the list.

There are very wide chemical and physical differences between the various substances whose physiological action we are about to discuss. They belong to no special chemical family; nor do they possess any distinctive element or group of elements in their composition. They are, moreover, equally dissimilar in their physical properties, for whilst most of them are liquid at ordinary temperatures, many are gaseous. Thus, the indifferent gases, hydrogen and nitrogen, by the simple exclusion of oxygen, will render patients completely unconscious—asphyxial anæsthesia (see p. 38). Carbonic acid, too, when mixed with oxygen, has been shown to be possessed of anæsthetic properties (p. 99). Then, as we shall presently see, nitrous oxide (N_2O) has every claim to be regarded as a true anæsthetic. And other gaseous bodies, such as ethylene or olefiant gas (C_2H_4), methyl chloride (CH_3Cl), and methyl oxide ($(CH_3)_2O$), have been employed, with more or less success, for inducing general insensibility. As we pass from bodies which are gaseous at ordinary temperatures to those which are liquid, we find upon the borderland several highly

volatile agents, derivatives of hydrocarbons, such as ethyl chloride (C_2H_5Cl), which boils at the body temperature, methyl bromide (CH_3Br), and aldehyde ($CH_3 . CHO$). Then, as instances of anæsthetics with somewhat higher boiling-points, we have ethyl oxide, or "ether" ($(C_2H_5)_2O$), ethyl bromide (C_2H_5Br), and amylene (C_5H_{10}), all of which are referred to in the preceding chapter. The next body generally placed upon the list is bichloride of methylene (CH_2Cl_2); but, as we shall see, this substance is, strictly speaking, improperly included. With a somewhat higher boiling-point than that of the preceding agent comes carbon bisulphide (CS_2), whilst acetate of methyl ($CH_3 . CO . OCH_3$) and acetone ($CH_3 . CO . CH_3$) are included amongst the general anæsthetics by some writers. Ethylidene chloride ($CH_3 . CHCl_2$), which has already been alluded to (p. 34), has a boiling-point (60° C.) almost identical with that of chloroform ($CHCl_3$). Amongst the less volatile bodies which possess general anæsthetic properties may be mentioned bichlorinated chloride of ethyl,[1] acetate of ethyl ($CH_3 . CO . OC_2H_5$), tetrachloride of carbon (CCl_4), ethylene chloride, or Dutch liquid ($CH_2Cl . CH_2Cl$), amyl hydride (C_5H_{12}), ethyl nitrate ($C_2H_5 . NO_3$), benzene (C_6H_6), and turpentine ($C_{10}H_{16}$). Alcohol ($C_2H_5 . OH$) can hardly be regarded as an anæsthetic, although, as is well known, it is capable of producing deep anæsthesia when administered in sufficiently large quantities. Finally, there are certain substances which are solid at normal temperatures, but which may, when administered in such a way as to enter the circulation, produce complete unconsciousness. Amongst these are: chloral ($CCl_3 . CHO$), acetal ($CH_3 . CH . (OC_2H_5)_2$), amyl chloride ($C_5H_{11}Cl$), and ethyl benzoate or benzoic ether ($C_6H_5 . CO . OC_2H_5$).

The term **general surgical anæsthesia** is commonly applied to that state of profound insensibility which is brought about by the action of a general anæsthetic, and which is of such a character as to allow of the performance of any surgical operation. The physiology of this state is necessarily exceedingly complex, the complexity increasing as we ascend the scale

[1] Mr. Hugh Candy informs me that there are two compounds which may be described as bichlorinated chloride of ethyl: (1) $CH_2Cl . CHCl_2$, boiling at 114° C.; and (2) $CH_3 . CCl_3$, boiling at 76° C.

(*d*) It must bring about not only general sensory paralysis, but such a loss of motor power as to render practicable the performance of surgical operations;

(*e*) Its action upon the sensory and motor systems must not be associated with greater excitement, greater convulsive movement, or greater interference with respiration, circulation, or other important vital processes than can be controlled or corrected by the anæsthetist;

(*f*) And lastly, it is essential that the agent employed shall be of such a kind that when it is withdrawn the whole organism will resume its functions, and return to that condition in which it existed when the anæsthetic was first applied.

All agents fulfilling these requirements may be allowed a place in the group of general anæsthetics; and the more completely any agent fulfils such requirements the higher will be its place in the group. Anæsthetics such as nitrous oxide, ether, and chloroform thus occupy high positions; whilst others, such as amylene, nitrogen, etc., have but a questionable right to be included in the list.

There are very wide chemical and physical differences between the various substances whose physiological action we are about to discuss. They belong to no special chemical family; nor do they possess any distinctive element or group of elements in their composition. They are, moreover, equally dissimilar in their physical properties, for whilst most of them are liquid at ordinary temperatures, many are gaseous. Thus, the indifferent gases, hydrogen and nitrogen, by the simple exclusion of oxygen, will render patients completely unconscious—asphyxial anæsthesia (see p. 38). Carbonic acid, too, when mixed with oxygen, has been shown to be possessed of anæsthetic properties (p. 99). Then, as we shall presently see, nitrous oxide (N_2O) has every claim to be regarded as a true anæsthetic. And other gaseous bodies, such as ethylene or olefiant gas (C_2H_4), methyl chloride (CH_3Cl), and methyl oxide ($(CH_3)_2O$), have been employed, with more or less success, for inducing general insensibility. As we pass from bodies which are gaseous at ordinary temperatures to those which are liquid, we find upon the borderland several highly

volatile agents, derivatives of hydrocarbons, such as ethyl chloride (C_2H_5Cl), which boils at the body temperature, methyl bromide (CH_3Br), and aldehyde ($CH_3 . CHO$). Then, as instances of anæsthetics with somewhat higher boiling-points, we have ethyl oxide, or "ether" ($(C_2H_5)_2O$), ethyl bromide (C_2H_5Br), and amylene (C_5H_{10}), all of which are referred to in the preceding chapter. The next body generally placed upon the list is bichloride of methylene (CH_2Cl_2); but, as we shall see, this substance is, strictly speaking, improperly included. With a somewhat higher boiling-point than that of the preceding agent comes carbon bisulphide (CS_2), whilst acetate of methyl ($CH_3 . CO . OCH_3$) and acetone ($CH_3 . CO . CH_3$) are included amongst the general anæsthetics by some writers. Ethylidene chloride ($CH_3 . CHCl_2$), which has already been alluded to (p. 34), has a boiling-point (60° C.) almost identical with that of chloroform ($CHCl_3$). Amongst the less volatile bodies which possess general anæsthetic properties may be mentioned bichlorinated chloride of ethyl,[1] acetate of ethyl ($CH_3 . CO . OC_2H_5$), tetrachloride of carbon (CCl_4), ethylene chloride, or Dutch liquid ($CH_2Cl . CH_2Cl$), amyl hydride (C_5H_{12}), ethyl nitrate ($C_2H_5 . NO_3$), benzene (C_6H_6), and turpentine ($C_{10}H_{16}$). Alcohol ($C_2H_5 . OH$) can hardly be regarded as an anæsthetic, although, as is well known, it is capable of producing deep anæsthesia when administered in sufficiently large quantities. Finally, there are certain substances which are solid at normal temperatures, but which may, when administered in such a way as to enter the circulation, produce complete unconsciousness. Amongst these are: chloral ($CCl_3 . CHO$), acetal ($CH_3 . CH . (OC_2H_5)_2$), amyl chloride ($C_5H_{11}Cl$), and ethyl benzoate or benzoic ether ($C_6H_5 . CO . OC_2H_5$).

The term **general surgical anæsthesia** is commonly applied to that state of profound insensibility which is brought about by the action of a general anæsthetic, and which is of such a character as to allow of the performance of any surgical operation. The physiology of this state is necessarily exceedingly complex, the complexity increasing as we ascend the scale

[1] Mr. Hugh Candy informs me that there are two compounds which may be described as bichlorinated chloride of ethyl: (1) $CH_2Cl . CHCl_2$, boiling at 114° C.: and (2) $CH_3 . CCl_3$, boiling at 76° C.

of evolution. It may be primarily divided into two parts, which may conveniently be termed (*a*) the theoretical and experimental, and (*b*) the clinical. The *theoretical and experimental physiology* will be first considered, the present chapter being devoted to this division. The *clinical physiology* will be subsequently discussed when dealing with each anæsthetic in the main body of the work, under such sections as "Effects produced by the administration," "Dangers connected with the administration," and "After-effects."

In studying the first division of our subject, we have at the outset to consider the various ways by which anæsthetics may enter the organism and exert that widespread and universal influence which is an essential feature of their action (§ 1). It will then be convenient to discuss, in general terms, the effects produced by anæsthetics upon the organism, and to arrange those effects in classes according to the stages in the administration at which they occur (§ 2). We shall then marshal the various facts and observations at our disposal which may throw light upon the intimate action of general anæsthetics upon the organic elements themselves (§ 3). And lastly, it will remain for us to examine the experimental data at our disposal concerning the effects produced by particular anæsthetics, not only upon the whole organism but upon its several systems (§ 4).

§ 1. THE PASSAGE OF THE ANÆSTHETIC INTO THE ORGANISM

Anæsthetics may act directly upon the organism by a simple process of imbibition and absorption. This is seen in the temporary arrest of development which takes place in germinating seeds when exposed to an atmosphere of ether or chloroform, and in the local loss of sensitiveness which occurs in the sensitive plant when similarly treated. Applied to the medusa, chloroform first arrests spontaneous movements and then brings about a state of diminished reflex activity.[1]

[1] Brunton, *Pharmacology and Therapeutics*, 3rd edit. p. 111.

In organisms possessing a circulatory system, the absorption by the circulating fluid of the gaseous or vaporised anæsthetic will lead with greater or less rapidity to generalised effects; and this is true, no matter in what part of the organism the absorption takes place. Arloing has, for example, shown that general anæsthesia will become established in the sensitive plant when its roots are subjected to the action of an aqueous solution of chloroform.[1] In cold-blooded animals, such as frogs, Claude Bernard showed that so long as the circulation was intact the immersion of one-half of the body in chloroformed water led to general anæsthesia; and he pointed out that, by reason of the comparatively slow elimination which takes place through the lungs, frogs are well fitted for this plan of inducing anæsthesia. General effects may also be produced in warm-blooded animals by the absorption of anæsthetics locally applied; but owing to the rapid elimination of volatile substances by the lungs, such effects are, as a rule, irregular and uncertain. Again, the gastro-intestinal tract may be made the site of absorption, as in the administration of chloral by the stomach, and of ether vapour by the rectum; but in this case also the results will be unreliable owing to the modifying influences exerted by digestion and other conditions. The most convenient channel for the introduction of gaseous and vaporised bodies into the general circulation is undoubtedly that presented by the respiratory passages, the large area furnished by the pulmonary alveoli and capillary network being particularly favourable to rapid absorption. Moreover, the blood circulating through the pulmonary arterioles and capillaries is specially suited for the reception and transmission of agents such as those we are considering; for immediately the blood has left the lungs it passes to the nervous centres in which take place, as we shall presently see, the essential changes necessary to the establishment of general surgical anæsthesia.

Having arrived at the pulmonary capillaries, anæsthetic gases and vapours are absorbed, according to physical laws, and the proportions taken up by the circulating blood will depend upon (*a*) the tension of the gas or vapour in the atmosphere

[1] Dastre, *op. cit.*

presented to the organism, (*b*) the solubility of the gas or vapour in blood, and (*c*) the temperature of the blood. The tension of the anæsthetic in the atmosphere presented to the organism will necessarily vary with barometric pressure and the external temperature. Snow was the first to draw attention to the laws governing the absorption of anæsthetic vapours, and his observations led him to enunciate the following proposition:—

> As the proportion of vapour in the air breathed is to the proportion that the air or the space occupied by it would contain if saturated at the temperature of the blood, so is the proportion of vapour absorbed into the blood to the proportion the blood would dissolve—

a proposition which was subsequently endorsed and applied by Paul Bert, and which has since been generally accepted.

The influence of external **temperature** in modifying anæsthesia was pointed out by Snow,[1] who showed that the percentage of chloroform vapour inhaled from a handkerchief or inhaler when the external temperature was high was considerably greater than would be breathed from a similar surface when the external temperature was low. Richardson[2] administered chloroform vapour to warm-blooded animals placed in a glass chamber, the temperature on one occasion being 40° F. and on another 80° F. With the lower temperature anæsthesia was preceded by excitement and vomiting, and was much delayed; with the higher these phenomena were absent and deep anæsthesia was rapidly induced.

This would appear to be the most convenient place in which to consider in an introductory and general manner the **respiratory phenomena of anæsthesia**; and it will, perhaps, be best to study these as they present themselves in practice rather than to discuss them from the standpoint of the experimental physiologist. To the experimentalist, free and efficient breathing is dependent mainly if not wholly upon an intact and active nervous and muscular mechanism. Drugs produce this or that change in the rhythm, rate, force, and amplitude of respiration by their action upon the nervous mechanism of breathing. Anæsthetics are regarded as sub-

[1] *Op. cit.* p. 34. [2] *The Hospital*, 17th March 1894, p. 431.

stances which first stimulate, then depress, and finally paralyse this mechanism. But to the clinical observer respiration is a function which is at all stages of anæsthesia liable to become intercurrently deranged, not so much from this or that quantity of the anæsthetic acting directly upon the nervous mechanism of breathing, but from incidental or intercurrent conditions which it is difficult or impossible either to realise or reproduce in the physiological laboratory.

In actual practice the respiration of a patient during the administration of an anæsthetic for a surgical operation may undergo changes dependent upon a large number of circumstances.

Thus (i.) *the local action of the anæsthetic upon the respiratory passages* may induce cough, retching, swallowing, "holding the breath," masseteric spasm, etc. Such phenomena are more common with ether than with chloroform, and with chloroform than with nitrous oxide; and they are, of course, most frequently met with when an anæsthetic vapour is administered in undue concentration.

(ii.) But provided no such disturbing influences arise, the normal breathing gradually tends to become somewhat deeper and quicker, chiefly from *stimulation of the respiratory centre by the circulating anæsthetic.* Some anæsthetics produce a more stimulating effect than others.

(iii.) In the case of pure nitrous oxide and of other gases and highly volatile vapours which admit of being administered with little or no atmospheric air, actual *deprivation of oxygen* may lead to exaggerated breathing, stertor, and tonic or clonic spasm of the respiratory muscles.

(iv.) In certain methods of administering anæsthetics (*e.g.* p. 272) some degree of *re-breathing* is permitted; and under such circumstances the incarcerated carbonic acid leads to a greater or less degree of hyperpnœa.

(v.) Again, *psychical impulses* may interfere with free respiration. This is sometimes seen early in an administration, when nervous, apprehensive subjects hold the breath till cyanosis arises, or when hysterical subjects cry or laugh till a state of incipient asphyxia is brought about. Moreover,

when normal consciousness has just been lost, rapid or suspended breathing may result from a dream or hallucination.

(vi.) As the patient passes into the second stage of anæsthesia, respiration often tends to become modified by *altered position, spasm, or swelling of parts within or about the upper air-passages* (see p. 443), or by *spasm of muscles directly concerned in the working of the respiratory pump* (see p. 462). In certain cases, indeed, complete arrest of breathing may thus arise. The extent to which respiration is interfered with will depend upon numerous circumstances, and particularly upon such factors as the calibre and conformation of the upper air-passages before anæsthesia, and the muscular development of the patient. Apart from the presence of morbid states, the influence of which will be fully considered below (p. 124), patients vary widely not only as regards the normal calibre of their air-passages, but as regards changes in that calibre during anæsthesia. The patient with free and wide passages and a thin neck may breathe so quietly under an anæsthetic that no sound whatever is produced, and as no extra work is thrown upon the respiratory pump, the chest and abdomen may hardly appear to move. On the other hand, the patient who, in his normal state, snores loudly at night, whose air-way is small, whose tongue is large and flabby, and whose neck is short and thick, may become so obstructed in breathing that mechanical means may have to be employed to maintain or re-establish free respiration. A *very slight* obstruction, such as that indicated by mild snoring, is positively an advantage in maintaining audible and good respiration (see p. 360); whilst a greater degree of occlusion of the air-tract will call into play violent and rapid respiratory acts, the depth and rate of which will vary with the air-limitation induced by the obstruction.

Various respiratory sounds may be emitted during the anæsthetised state, and many of them will be found to act as important clinical guides. In addition to the ordinary sound produced by the passage of air in and out of the upper air-channels, there are numerous superadded or adventitious sounds which deserve attention. These may be divided into inspiratory and expiratory, the former being as a rule snoring

or stridulous, the latter phonated in character. In the anæsthetised patient respiration may take place either through the nose or mouth; or the respiratory current may enter by the former and leave by the latter channel. To the snoring sounds of anæsthesia the term "stertor" is commonly applied, although some authors include under this head inspiratory sounds devoid of snoring characters.

Dr. R. L. Bowles,[1] who has devoted considerable attention to the subject of stertor, speaks of six varieties. In (1) *Nasal* stertor a sniffing sound is produced by approximation of the alæ nasi. In (2) *Buccal* stertor the lips and cheeks flap to and fro with inspiration and expiration. In (3) *Palatine* stertor the soft palate vibrates, and the stertor may acquire a nasal or oral character according to the course of the current. In (4) *Pharyngeal* stertor the base of the tongue vibrates against the pharyngeal wall. In (5) *Laryngeal* stertor the vocal cords vibrate. And in (6) *Mucous* stertor there is mucous secretion in the trachea and larger tubes.

Dr. Bowles very properly draws attention to the fact that stertor always indicates a greater or less degree of obstruction, and this is of great importance in administering anæsthetics. The commonest form of stertor during the anæsthetised state is that which is produced by the tongue vibrating against the pharyngeal wall. This vibration is generally regarded as dependent upon a flaccid or paralytic state of the tongue; but I am convinced that, in many cases at least, it is dependent rather upon spasm of muscles drawing the base of the tongue backwards during inspiration than upon a paralytic state of the organ. I have elsewhere[2] shown that with pure nitrous oxide the stertor is distinctly spasmodic, and that with mixtures of nitrous oxide and oxygen this stertor lessens as the oxygen percentage rises, till with certain mixtures the snoring is identical in all its characters with that of ether or chloroform anæsthesia. In certain subjects anæsthetics may cause so much muscular spasm about the fauces, pharynx, floor of the mouth, and larynx, that an obstructive stertor is produced and life is thereby threatened (see p. 448). In some cases, too, an engorged state of the tongue obviously contributes to the production of stertor. Whilst stertor is the audible expression

[1] *On Stertor and Apoplexy.*
[2] *Trans. Roy. Med. Chir. Soc.* vol. lxxxii.

of a greater or less degree of obstruction *above* the larynx, stridor always indicates a tendency towards occlusion of the larynx itself. Two varieties of laryngeal stridor present themselves in practice. The first of these is a short, deep, and coarse sound caused by collapse or falling together of the superior aperture of the larynx. The latter is a prolonged and high-pitched sound, sometimes altering in pitch during an inspiration, and dependent upon laryngeal spasm rather than collapse. In surgical practice laryngeal stridor may arise from the direct effect of the anæsthetic vapour, from the presence of mucus or other adventitious substances, or as the reflex result of sensory stimuli in various parts of the body (see p. 351). As regards expiratory adventitious sounds, these are, as a rule, phonated and dependent upon approximation of the true vocal cords. As a general rule any phonated sound indicates a moderate degree of anæsthesia. For further remarks the reader is referred to pp. 362 and 447.

(vii.) When once the patient has been brought well under the influence of the anæsthetic, the respiration may be made to vary with the *quantity of the anæsthetic given*, becoming deeper, quicker, and (usually) more stertorous with more, and shallower, slower, and (usually) less stertorous with less. Such changes, however, are not always dependent only upon dosage, but also upon variations in the amount of air given. When toxic quantities of the particular agent are administered respiratory depression and paralysis ensue (p. 464).

(viii.) In addition to the respiratory changes which are strictly dependent upon the action of the anæsthetic itself upon the respiratory centre, there are other changes which are dependent upon the *blood supply to that centre.* Other factors remaining the same, the better the arterial supply the better the breathing and *vice versa* (see pp. 471 and 477).

(ix.) Any hindrances to free thoracic and abdominal movement, such as *tight-lacing*, the adoption of *certain postures*, etc., may readily introduce an asphyxial element into the administration (p. 461).

(x.) In certain cases "*physiological apnœa*" may be met with. It is most common under nitrous oxide and oxygen, but it may be met with under other anæsthetics, and

is nearly always preceded by a phase of rapid and deep breathing.

(xi.) *Cheyne-Stokes breathing* is sometimes seen, particularly in elderly and feeble subjects under chloroform.

(xii.) In practice it will be found that the rate, rhythm, and amplitude of respiration may undergo modifications dependent upon the *operation* itself. Traumatic, thermal, and electrical stimuli are all capable of modifying breathing, one of the most powerful stimuli being the stretching of any of the natural orifices of the body. In the vast majority of cases traumatic and other stimuli augment rather than diminish respiratory movements. Thus, other factors remaining the same, the breathing of an anæsthetised patient who is not undergoing an operation is quieter, slower, and shallower than when a traumatic stimulus is at work. This fact is particularly evident when, for some reason or another, a patient has been anæsthetised for a considerable time before the first incision is made; the quiet breathing at once becoming and remaining deeper in response to the cutaneous stimulus. But surgical stimuli may arrest respiration either by causing mechanically obstructed breathing (see pp. 142 and 449) or by reflex spasm of respiratory muscles. If, for example, an operation be begun whilst the patient is in the second stage of anæsthesia, temporary or even prolonged arrest of breathing, due to reflex contraction of muscles within or about the respiratory tract, may occur (see p. 347), and in certain subjects such arrest may be very hazardous. This is an exceedingly important fact in actual practice. Again, even in the later stages of anæsthesia a somewhat similar state may be induced; but whether under these circumstances the arrest is due to reflex spasm or to an inhibitory (paralytic) effect upon the respiratory centre it is at present difficult to say (see p. 471).

Finally, in considering the factors which may modify respiration during anæsthesia, we must not omit to mention the remarkable effects of lip-friction (see p. 361).

The above facts teach us that, in addition to what may be termed the true physiological effect of an anæsthetic upon the nervous mechanism of respiration, numerous incidental or intercurrent conditions capable of materially affecting breathing

may come into play during anæsthesia and introduce an asphyxial factor into the administration. Some of these conditions are obviously due to the customary plan of introducing anæsthetics into the circulation through the respiratory passages; but others are, as we have seen, dependent upon obstructive or spasmodic states arising not from the action of the anæsthetic upon the respiratory centre, but from its action upon other centres within the cerebro-spinal axis. It is often a very difficult matter to decide whether a particular state into which a patient has passed has been brought about by the anæsthetic itself, or by anoxæmia dependent upon one or other of the causes to which reference has been made. So closely, indeed, may the symptoms of anoxæmia resemble those of anæsthesia, so nearly may the phenomena of anæsthesia simulate those of anoxæmia, and so easily may the one condition be made to intensify the other, that we cannot help being struck by the analogy existing between the two states.

If any justification be needed for entering into such minute details as those just given, it must be found in the fact that in the vast majority of difficulties and dangers encountered during surgical anæsthesia some slight interference with the respiratory functions constitutes the first link in the chain of alarming symptoms. Without free respiration, success and safety in anæsthetising are equally unattainable. It is often urged by experimental physiologists that there are no essential differences between the phenomena of anæsthesia, as seen by them in the laboratory, and those met with clinically in the operating theatre. But just as the clinical observer is comparatively ignorant of the technique of the physiologist, so is the latter comparatively unaware of the numerous ways in which respiratory complications may arise during the administration of anæsthetics to human subjects. Whether the physiologist can experimentally reproduce the various respiratory phenomena to which I have just referred—all of which are unquestionably met with clinically—I cannot say. If he cannot, it is fair, I think, to assume that there are certain differences between the behaviour of man and of lower animals under anæsthetics that may explain accidents hitherto obscure.

The rapidity with which the particular anæsthetic will produce its effects will greatly depend upon the rate and depth of the respiratory movements and the activity of the pulmonary circulation, a quick and deep respiration and a forcible and full pulmonary blood-stream being favourable to absorption and rapid transmission of the anæsthetic.

We must not forget, in conclusion, that whilst the pulmonary blood-stream is the great medium for the reception and transmission of anæsthetics, it is also the great medium for their elimination, and for the escape of carbonic acid. There is no good evidence that any of the anæsthetics now in use are themselves decomposed during their period of association with the circulating blood; but one must speak guardedly upon this point pending further investigation. As regards carbonic acid, it would seem that whilst its production is diminished during anæsthesia (see pp. 60 and 83), there is no obstacle to its elimination from the lungs provided that the respiratory passages are free, and that expirations escape into the surrounding atmosphere. But when breathing becomes, as it so often becomes, mechanically obstructed by more or less continuous stertor, it may be regarded as certain that this gas will remain to some extent incarcerated below the obstruction, and that in consequence of this its escape from the pulmonary blood will be retarded. Again, it is customary in certain methods of administration for the patient to breathe backwards and forwards into a bag, fresh air being only occasionally allowed, and under these circumstances also there must be a similar increase in the carbonic acid blood tension owing to the retention of the excreted gas within the upper air-passages. The experiments of Haldane and Lorrain Smith[1] with regard to the effects of breathing different proportions of air and carbonic acid, of air with less than the normal percentage of oxygen, and of hydrogen, are interesting in this connection.

§ 2. A GENERAL SURVEY OF THE EFFECTS PRODUCED BY ANÆSTHETICS UPON THE ORGANISM

Having entered the pulmonary blood-stream, general anæsthetics are enabled to exert their influence upon all parts

[1] *Journ. Path. and Bact.* vol. i., 1892-93, p. 168.

of the organism, and to affect the various systems of that organism in a more or less definite and characteristic manner. As already indicated, there is a considerable difference between the effects produced by one anæsthetic and those produced by another, the organism and the means adopted for introducing the anæsthetic remaining the same. This is exemplified in the behaviour of the same patient under ether and chloroform, each administered in precisely the same way, and with the same percentage of air. Then, as everyday experience teaches us, the same anæsthetic may produce very different effects upon the same subject, according to the system or method adopted for administering it. This is well seen in the case of nitrous oxide, which is capable, according to the plan of administration adopted, of producing an asphyxial or a non-asphyxial form of anæsthesia. Again, the phenomena which arise during the administration of an anæsthetic will necessarily depend upon the rapidity with which the anæsthetic enters the circulation, and the quantity which is present within the circulation at the particular time. This was clearly demonstrated by Snow as regards chloroform, and is true of other anæsthetics. In the next place, it is obvious that the effects produced by an anæsthetic will very largely depend upon the organism subjected to anæsthetic influence. This, as Dastre points out, is strikingly evident when a bird, a mouse, a frog, and a sensitive plant are exposed, within a bell-jar, to the influence of ether vapour; the four organisms being affected in the order named. The influence of this important factor is also obvious when we compare the effects produced by chloroform upon man and those resulting from its administration to lower animals. And it is important to bear in mind that organisms, apparently similar to one another in all essential details, may display very different phenomena, even though precisely the same plan be adopted for inducing general anæsthesia. This is unquestionably the case with human beings, the type of subject, as we shall presently see (p. 114), being one of the most, perhaps the most important factor in determining the effects which this or that anæsthetic may bring about.

Little is accurately known as to the changes which anæsthetic gases and vapours produce in the blood itself: but

the facts which are at present at our disposal will be discussed when dealing with each anæsthetic. Speaking generally, it would seem that most anæsthetics enter and leave the blood without producing in it any distinctive or important changes save those which, as we shall presently see, must inevitably result from the interference with normal respiration necessarily incidental to the plan of administering anæsthetics by inhalation. Sansom, Wittich, Bötticher, and other observers have, however, described alterations in the red corpuscles,[1] and, according to the Glasgow Committee of the British Medical Association, disintegration of these corpuscles takes place within the pulmonary capillaries during inhalation.[2] Grube states that urobilinuria takes place two or three days after anæsthesia, pointing to a destruction of red corpuscles as a result rather than an accompaniment of the administration. According to Richet, blood holding an anæsthetic in solution always preserves, when shaken with air, its capacity for fixing the same proportion of oxygen.

Whilst the nervous, the respiratory, the circulatory, the digestive, the muscular, and the glandular systems are one and all affected by anæsthetics, it is the first named of these systems that is primarily and chiefly involved. This is not surprising when we reflect that the **nervous system** is, as compared to others, far more delicate in its mechanisms, and is, therefore, more likely to show signs of disturbance under the influence of protoplasmic poisons such as those we are now considering. The most highly evolved parts of the central nervous system are those which are first affected. This is true of all organisms, whether high or low in the scale of evolution. Claude Bernard showed, by a series of experiments on frogs, that ether and chloroform primarily and chiefly affected the sensory centres of the cerebro-spinal axis, and that the sensibility of sensory nerve-endings was destroyed, not from the action of the anæsthetic upon those endings, but from its action upon the centres themselves. He pointed out, however, that, as in death of sensory nerves from want of nutrition, the peripheral ends first showed signs of suspended function; that the trunks were next involved; and that finally the roots shared in the process. In the case of man and

[1] Dastre. [2] *British Medical Journal*, vol. ii., 1880.

other mammals it would seem that the cerebral cortex is, as a rule, affected before any other part of the central nervous system; that in all probability the basic ganglia and cerebellum are next involved; that the sensory tracts and centres of the cord which connect the brain with the periphery next suffer; that the cerebro-spinal motor tracts and centres are then paralysed; and that finally the automatic respiratory and cardiac centres cease to act. It is, however, difficult to speak with anything approaching precision on this point; and it must be remembered that great variation exists in apparently similar subjects. In a large number of cases the earliest sensation experienced by the patient is one of "numbness and tingling" in the extremities, and this, as the author has frequently satisfied himself, may exist without any disturbance of consciousness. Moreover, as we shall presently see, a true analgesic state may occasionally be induced. Claude Bernard expressed the belief that the brain, playing the rôle of a principal nerve-centre, influenced the secondary nerve-centres of the spinal cord, although it was incapable of being itself influenced by the latter; and so far as the cord was concerned he found that, just as in the case of sensory nerves themselves, the function of excitability was lost from below upwards, the lumbar, dorsal, cervical, and bulbar regions being affected in the order named.

In the initial stages of anæsthesia the application of traumatic or other stimuli may evoke responses which have all the appearance of, and in one sense are, conscious responses; but owing to a want of synthesis in the sensory impressions received, and to disturbances within the perceptive centres themselves, pain is either not appreciated as pain, or, if appreciated, is not remembered. Whilst some impairment of common sensibility is frequently met with at the outset of inhalation, typical analgesia, that is to say, the absence of the power of appreciating pain, whilst consciousness, tactile sensibility, and all other faculties are preserved, is rare; and with our present knowledge we are unfortunately unable to depend upon establishing this condition. The best results in this direction have been attained by the combined action of morphine and small quantities of chloroform (see p. 422).

True analgesia is, moreover, not uncommonly observed, and particularly in feeble subjects, during recovery from deep anæsthesia. According to Dastre, the analgesia of the induction stage depends upon the sensory nuclei of the cord or cerebral ganglia being affected by the anæsthetic before the cortical centres, so that sensory impressions are blocked on their way to the perceptive areas of the cerebrum. This author suggests that this abnormal sequence of effects may be due either to diminished excitability of the hemispheres, or to increased excitability of the spinal and ganglionic sensory centres. Other physiologists, however, believe that the block takes place in the cerebral cortex. It is unfortunately impossible to induce and maintain pure analgesia, although some degree of it is a common incident when anæsthetics are administered in graduated and small quantities.

The order in which the special senses are invaded is not precisely known. Sight is generally lost before hearing. Dastre points out, and I can corroborate his assertion, that patients, although unconscious of their surroundings, may sometimes be made to reflexly repeat or pronounce a sequence of words. The same author draws special attention to the fact that before anæsthetics bring about their paralysing influence upon the various and successive parts of the nervous system, they induce a pre-paralytic state of excitement, and it thus happens that we find certain excitation phenomena belonging to the excitement stage, through which a certain centre is passing, side by side with the paralytic phenomena of another centre. Dastre also points out that when an equal excitation affects both the augmentor and the inhibitory parts of a nervous mechanism, it is the inhibitory or moderating influence which predominates.

Although the sensory system is primarily and fundamentally affected by anæsthetics, the motor functions are also profoundly modified. The changes, indeed, which the **motor system** undergoes in the different stages of anæsthesia are of great interest and importance. Claude Bernard found that in the deeply anæsthetised frog motor nerves preserved their excitability. In the sciatic nerve the central terminations of the sensory filaments were anæsthetised, but not the motor filaments. In

the chloroformed dog the application of vinegar to the tongue produced no salivary secretion; whereas stimulation of the chorda tympani—the motor nerve of the submaxillary gland—provoked salivation. As in the case of the sensory system, excitation phenomena first appear, to be subsequently followed by phenomena of a paralytic nature. In the earlier stages of the administration the centres capable of executing complex and co-ordinated movements are first affected. As the administration proceeds, those centres which evoke simple muscular acts fall victims to anæsthetic influence. And lastly, the automatic motor centres of respiration and circulation fail to act and death ensues. The muscular phenomena of anæsthesia —the manifestations of changes within the motor system—are worthy of greater attention than has hitherto been bestowed upon them; for, as we shall see in the clinical sequel, many, and perhaps most, of the complications of anæsthesia are to be explained by disturbances of breathing dependent upon muscular spasm within or about the air-passages and lungs. The reader is therefore referred to other parts of this work. In the present connection we may say that the muscular system is capable of being affected both directly and indirectly by general anæsthetics. Little is definitely known as to the *direct* effects of these substances upon muscle. Claude Bernard found that the application of etherised or chloroformed water to muscles induced rigidity and loss of sensibility, and that cloudy changes appeared microscopically. Ringer's experiments with regard to the action of anæsthetics upon the muscular tissue of the frog's heart will be subsequently considered. It would seem that when muscles are subjected to anæsthetic action they gradually lose their power of responding to given stimuli. Thus, when the peripheral end of the sciatic nerve is stimulated during the administration of chloroform, a progressive diminution in the work done by the muscle takes place, the diminution becoming more marked as the duration of anæsthesia increases (Dastre). Most of the muscular phenomena of anæsthesia are dependent upon *indirect* (nervous) action.

The following **muscular phenomena** may be witnessed in the human subject during the inhalation of an anæsthetic:—

(1) *Uncontrollable "nervous" movements*, such as tremor, hysterical outbursts, etc.

(2) *Conscious voluntary movements*, such as correcting the faulty fitting of an inhaler, adjusting the head to a comfortable position, etc. These may or may not be associated with some degree of analgesia. Speech, if uttered, is rational and intelligible.

(3) *Sub-conscious voluntary movements.* These are often very interesting. A patient may, for example, attempt to remove a mouth-prop placed between his teeth under the impression that it is a pipe or cigar. Irrational verbosity is common in certain types of subjects. A movement originally initiated during normal consciousness may become enormously exaggerated as will-power lessens. Hardly noticeable movements of the feet may, for example, gradually increase to uncontrollable stamping.

(4) *Unconscious excitement or intoxication movements.* These may vary from the simple laughter of intoxication to the most violent maniacal excitement. Incoherent but articulate speech may accompany these movements, or inarticulate muttering—an evidence of a somewhat deeper anæsthesia—may be present.

(5) *Simple tonic spasm.* This may be local or general, and it may occur in all stages of anæsthesia. In the vast majority of cases tonic spasm presents itself only during the induction period; but exceptional cases may be met with in which spontaneous rigidity comes on even in the deepest anæsthesia. In many of these latter cases an intercurrent asphyxial factor is present. Reflex tonic spasm is most common in light anæsthesia; it may, however, arise more particularly in response to *certain* stimuli in profound narcosis. The importance of the factor of tonic spasm in chloroform anæsthesia will be specially discussed hereafter. Phonated expiratory sounds are not uncommonly associated with muscular spasm.

(6) *Clonic spasm.* This may occur with all the usual anæsthetics; it is, however, most common with pure nitrous oxide. With this agent clonic movement is, as the writer has shown, of anoxæmic origin; and there is reason to

believe that even with other anæsthetics such movement is often of a similar nature. Paul Bert[1] found that when an animal was anæsthetised and then submerged, asphyxial convulsions were still produced, although they were less marked than when asphyxia was brought about in the non-anæsthetised state. Convulsive phenomena are sometimes witnessed when a poisonous quantity of chloroform has been swallowed (Taylor). For further remarks see pp. 221 and 350.

(7) *Slow, spontaneous, co-ordinated movements,* particularly of the hands and arms, sometimes occur in deep anæsthesia; but their nature is unknown.

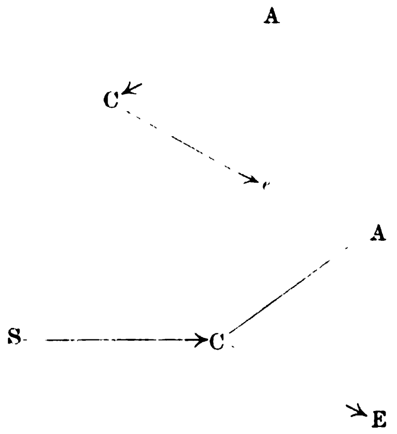
(8) *Fine tremor* of the legs, arms, or whole body is sometimes met with in moderately deep anæsthesia, especially under ether.

It is difficult to say what particular parts of the central nervous system are involved in the development of the muscular phenomena just described. As regards the disorderly and convulsive movements of the early stages of anæsthesia, Duret attributes them to excitation of the psychico-motor centres; whilst Dastre considers them to be caused by excitation of the bulbo-spinal sensory tracts. As already indicated, many of the muscular phenomena of anæsthesia are in reality asphyxial, or more properly anoxæmic in their origin.

The **reflex phenomena of anæsthesia** are of considerable interest; for by carefully studying them it is possible to produce and maintain any desired degree of narcosis. It is a mistake to suppose that it is the duty of the anæsthetist to abolish all reflex acts. There are, indeed, certain reflexes which it may be impossible to annul without incurring grave risk. All that is needed in surgical practice is to abolish inconvenient reflexes, in other words, to prevent muscular movement, swallowing, coughing, retching, etc.; and this can generally be done with perfect safety. During the earlier stages of an administration, whilst volition and control are disappearing, reflex acts may be found to be exaggerated; but as anæsthesia deepens they tend to vanish in a more or less definite order. When only a slight degree of anæsthesia is

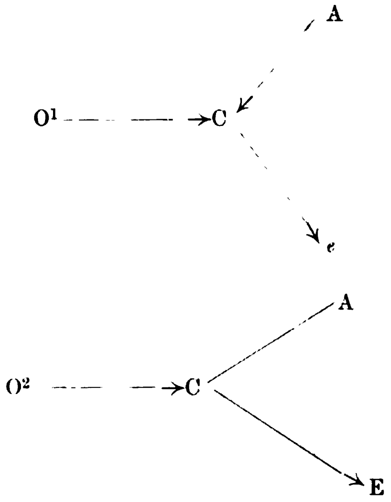
[1] *Acad. des Sciences,* 18th March 1867.

present reflex responses to stimuli may have all the external characters of conscious and purposive responses, but no purpose or consciousness may be present, the cerebral cortex being at the moment unable to interpret the sensory stimuli which reach it. During the second stage of anæsthesia (p. 62) there is usually a brisk response to most stimuli—traumatic, thermal, electric, and chemical. As will be particularly pointed out hereafter, respiratory spasm of an aggravated or even dangerous degree may be reflexly induced by the commencement of an operation during imperfect anæsthesia. Various degrees of cardiac inhibition may also be reflexly brought about by traumatic stimuli applied during this stage; but, as will be subsequently seen (pp. 91 and 143), there is no good evidence that such inhibition is specially hazardous, or that it is specially confined to this stage. In actual practice it is found that patients vary widely in regard to their reflexes—some remaining passive to the most violent stimuli, even during a very light anæsthesia, whilst others display persistent reflex phenomena in response to comparatively slight excitation. Moreover, the presence or absence of a given reflex is often dependent upon the presence or absence, at the moment, of some other excitation. Thus, if during a com-



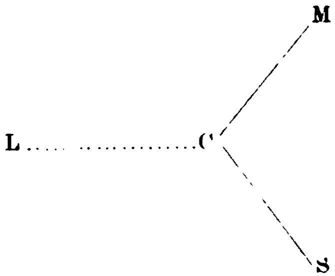
paratively light chloroform anæsthesia an afferent excitation (A) be applied to the cornea (as by touching it with the

finger), and the centre (C) be only partly paralysed, a very slight efferent effect (*e*) may result—the lid either closing very feebly or not at all. But if, during the same degree of chloroformisation, a strong stimulus (S) be applied, as, for example, by making a cutaneous incision, or roughly rubbing the lips with a dry towel, a precisely similar afferent impulse (A) will induce an exaggerated efferent effect (E), in other words, the corneal reflex will become brisk. This is often seen in the spurious chloroform sleep of children (p. 337). It may also be seen when a double surgical operation has to be performed. Thus the afferent stimulus (A) may only



produce a trifling efferent motor effect (*e*) when the operation (O^1) is in progress; but directly the surgeon commences (O^2) the effect may be a greater and more widespread motor effect (E). Numerous other interesting reflex phenomena might be quoted. For example, a cough, an act of swallowing, an act of retching, laryngeal spasm, and even stertor dependent upon the base of the tongue being drawn spasmodically over the laryngeal orifice, may one and all be brought about by surgical stimuli applied to parts of the body far removed from the site of the reflex phenomenon. The following example, typical of others, will show the importance

of carefully studying reflex conditions. Let us suppose that a moderately deeply anæsthetised patient is undergoing an operation, and that at a particular juncture swallowing movements (S) are being excited by the surgical manipulation (M). As a result of this there is necessarily some temporary interference



with the air supply to the lungs, and hence some degree of cyanosis. By briskly rubbing the lips (L) with a cloth the reflex act (MCS) is at once inhibited, the air-way is again rendered patent, cyanosis disappears, and free respiration takes place. The corneal, laryngeal, pharyngeal, rectal, vesical, and genital reflexes are usually amongst the latest to disappear. In dogs the patellar reflex is at first exaggerated; it then lessens, and finally disappears before the corneal reflex is lost. The spinal cord undoubtedly preserves its power of transmitting sensory impulses till the very last: for certain stimuli may evoke reflex effects (particularly upon respiration) even when a very profound degree of anæsthesia is present. According to Richet, stimulation of the vagus will slow or even arrest the heart movements in all stages of anæsthesia. It is difficult to say with any certainty at what particular point in the course of anæsthesia the vaso-motor centres become paralysed, but it is generally held that they retain their controlling function till quite late. The cardio-inhibitory and cardio-accelerator centres are probably more active in light than in deep anæsthesia, although there is ample evidence to show that even in the most profound narcosis stimuli may still reflexly affect cardiac action (see pp. 144 and 484). As to the respiratory centre, it appears to remain sensitive to certain stimuli till just before its automatism is finally abolished. If

the vagi be divided during deep anæsthesia the usual respiratory phenomena still appear. In his experiments upon dogs Dastre found that the labio-mental reflex—a localised movement of the lower lip induced by exciting the mucous membrane of the upper gum at the level of the incisor teeth—was one of the last to disappear, and he therefore termed it the "ultimum reflex." In the case of human beings, lip-friction certainly stimulates respiration, even in the most profound chloroform anæsthesia (p. 361).

It is generally admitted that **respiratory exchanges** are greatly modified during anæsthesia. Thus, Rumpf found with ether, chloroform, alcohol, and chloral a decrease of 40 per cent, and a corresponding diminution of temperature. Richet[1] found that chloralised dogs only produced on the average ·600 gm. of CO_2 per kilo. per hour, whilst normal dogs produced 1·200—in other words, the chemical activity of the organism was reduced 50 per cent. Richet regards it as probable that the greater part of this decrease is dependent upon complete muscular relaxation, but thinks it likely that glandular and other tissues also undergo diminished oxidation during anæsthesia.

By carefully studying the effects produced by anæsthetics upon man, observers have from time to time proposed to speak of different **degrees or stages** in their action. Thus Snow states that Flourens recognised four stages. In the first of these there was paralysis of cerebral functions; in the second, paralysis of cerebellar functions; in the third, paralysis of the functions of the spinal cord; and in the fourth, paralysis of the functions of the medulla oblongata.

Snow spoke of five degrees.[2] In the first of these consciousness was not abolished; there were various disturbances of special senses, and some diminution of common sensibility. In the second, the mental functions were impaired but not necessarily suspended; there was laughing, talking, and excitement. In the third, voluntary motion was suspended, but involuntary movements continued; rigidity and spasm occurred, muttering was common, and although there was no consciousness or perception of pain, the subject might cry out during a

[1] *Dict. de Physiologie.* [2] *Op. cit.* p. 35.

surgical procedure. In the fourth, the breathing became stertorous, the pupils dilated, and the muscular system relaxed. In the fifth and last degree the breathing became difficult, feeble, or irregular, and was sometimes performed only by the diaphragm; respiration then ceased, and the heart, which for a time pulsated distinctly, soon failed as in death from asphyxia.[1]

Dastre[2] describes four periods: (1) suspension of brain functions—hence sleep; (2) abolition of functions of spinal cord considered as a conducting organ of sensibility—hence complete anæsthesia; (3) abolition of motor functions of cord; and (4) bulbar paralysis—cessation of respiration and circulation. The objection to Dastre's classification is that there is good evidence to show that even in deep anæsthesia both sensory and motor impulses may be transmitted by the cord.

Taking all circumstances into consideration we may, I think, speak of the following degrees or stages in anæsthetisation:—

TABLE showing the degrees or stages in the action of the chief general anæsthetics upon the human organism, and the effects which usually characterise these stages.

Degree or Stage.	Effects.
1. **Stage of disordered consciousness and analgesia.**	Excessive ideation; disturbances of judgment, control, and volition. Analgesia. Vertigo and loss of power of maintaining equilibrium. Pleasurable or distressing sensations. Disturbances (exaggeration or diminution) of common sensibility and of special senses. Misinterpretation of external impressions. Emotional disturbances, *e.g.* laughter and crying. Reflexes well marked and often exaggerated; sensory stimuli may produce co-ordinated and apparently purposive movements. Loss of power of remembering (fixing) sensory impressions. Dreams. Rise of blood-pressure and increase of cardiac action. Respiration increased but regular and free, unless interfered with by emotional causes or by direct irritation of anæsthetic, inducing cough, "holding of breath," laryngeal spasm, retching, or vomiting. Pupils dilated.

[1] As we shall presently see (p. 87), Snow also believed that *with concentrated chloroform atmospheres* the heart might cease before respiration. [2] *Op. cit.*

TABLE—*continued*

Degree or Stage.	Effects.
2. Stage of unconscious reflex activity.	Complete loss of consciousness. Delirium; articulate speech passing into unintelligible muttering. Respiration still deeper and quicker than normal; often irregular and impeded by General tonic muscular spasm, deglutition, closure of glottis, spasm of jaws, etc. Clonic muscular spasm. Reflexes still persist; but motor results of stimuli devoid of purposive character. Inarticulate phonated (expiratory) sounds. Coughing, retching, vomiting. Heart's action still excited (much dependent on character of breathing). Pupils smaller.
3. Stage of surgical anæsthesia or coma.	General muscular relaxation. Breathing regular, often softly snoring or stertorous. Decrease of respiratory exchanges; fall of temperature. Increasing fall of blood-pressure (chloroform). Heart's action weakened, variable degree of cardiac dilatation. Loss of conjunctival, pharyngeal, laryngeal, patellar, and most but not all reflexes. Pupils larger.
4. Stage of bulbar paralysis.	Loss of bladder, rectal, peritoneal, and respiratory reflexes. Loss of cardiac reflexes (?). Breathing becomes shallow. Increasing lividity or pallor. Breathing ceases (paralysis of respiratory centres). Paralysis of vaso-motor centre (?). Feeble, irregular cardiac action; paralysis of cardiac ganglia and myocardium. Widely dilated pupils. Separation of eyelids. Death.

The above table is only intended to indicate in a general sense the order in which the various effects produced by anæsthetics make their appearance. As already mentioned, there are so many factors capable of modifying the course of anæsthesia that it is exceedingly difficult, if not impossible, to generalise.

§ 3. ON THE INTIMATE PHYSIOLOGY OF GENERAL ANÆSTHESIA

Although many of the problems which have for years surrounded the subject of anæsthesia may now be regarded as solved, there remains one problem which has hitherto defied all attempts at solution, viz. the nature of the changes within the central nervous system which are capable of bringing about a state of general anæsthesia. As we have seen, this state may be induced by a variety of therapeutic agents; but it may also be established, in a more or less complete and typical form, in numerous other ways.

There is, in natural sleep, some degree of anæsthesia; the degree varying in different subjects, and in the same subject according to the special circumstances which may be present. The auditory, olfactory, visual, and tactile stimuli which will arouse one person may not even disturb the slumbers of another. But apart from the question of anæsthesia, there are several other interesting points of similarity between natural and artificial sleep. Thus we find in regard to both states that a rapid flow of confused ideas immediately precedes unconsciousness; that vivid dreams, dependent upon some suggestion or incident prior to unconsciousness, are remembered on awakening[1]; that the muscular system is relaxed; that complicated reflex phenomena may be elicited; that the eyelids are closed; that the pupils are, as a rule, contracted[2]; that the production of heat is reduced; that the exhalation of carbonic acid is diminished; and that respiration is often snoring or stertorous in character. It has also been urged that both in natural and in artificial sleep cerebral anæmia is present; but whilst it is undoubtedly true that in the former state a general fall of arterial tension occurs, and that as a consequence of this the blood supply to the brain becomes reduced, the analogy only holds good so far as *chloroform*

[1] This is only true as regards very short administration of anæsthetics.

[2] As regards the pupils, the analogy only holds good when we compare the sleeping subject with the anæsthetised patient who is allowed to remain free from all traumatic and other stimuli, and who is, moreover, free from all intercurrent asphyxial condition.

anæsthesia is concerned. With nitrous oxide and with ether no such fall in pressure is observed, and the blood supply to the brain is therefore not lessened. The similarities between natural and artificially induced sleep are most striking when we compare heavy natural sleep with the state of "false anæsthesia" or "chloroform-sleep" to be subsequently discussed (p. 331). It is not, indeed, beyond the limits of possibility that future research may indicate that a similar change within the elements of the cerebral cortex is responsible, at all events in part, for the phenomena of both states. At the present time little if anything is definitely known as to the nature of the physiological changes which are involved in the production of sleep; but the existence of the analogies here referred to may perhaps be taken to support the view that this state is dependent upon the presence within the circulation of some chemical substance capable of exerting, in association with other factors, temporary soporific influences. Such a view, however, is by no means generally accepted; for, according to the most recent hypothesis,[1] the unconsciousness of natural slumber is to be regarded as resulting not so much from changes induced by this or that agent or agency within the "neurons" and other structures which collectively constitute the independent elements of the nervous systems, but from simple alterations of a histological character affecting the dendritic processes which connect individual neurons one with another. According to some authors a retraction of these processes takes place, with the result that the individual neurons become isolated (Lépine and Duval), whilst according to others a widening in these communicating paths occurs, so that nervous impulses more readily travel from one cell system to another (Lugano). If we adopt the former view, then the isolation of independent cell systems is to be regarded as the immediate cause of sleep; whilst according to the latter the widening of impulse-paths is to be looked upon as responsible —such widening leading to confusion of thought and finally to unconsciousness. It is hardly necessary to add that these hypotheses have little to support them; nor do they materially

[1] For many interesting points in connection with sleep I am indebted to Dr. Bradbury's lectures. See *Lancet*, 24th June 1899, p. 1685.

help us in our present inquiry into the nature of anæsthesia. It is an interesting fact that it is frequently possible, by very gradually administering chloroform during sleep, to make the natural pass into the artificial state (p. 197). Natural sleep or a feeling of drowsiness is, moreover, a common sequel of anæsthetisation.

Extremes of temperature are capable of materially modifying, and, under certain circumstances, destroying normal consciousness. Claude Bernard showed that when frogs were submitted to a temperature of 0° C. anæsthesia resulted; as the temperature rose, vitality returned; as 30° to 35° was reached, vitality again lessened; at about 37° anæsthesia again supervened; and at 40° the animal died. Richet[1] obtained similar results with lobsters. He found, however, that rabbits, when exposed to intense cold, still remained sensitive to traumatic excitation, but they reacted slowly. Spontaneous movements were the first to become affected; then reflex functions were suspended; and, finally, muscular resolution took place. Claude Bernard believed that in cold-blooded animals an increase in temperature induced an asphyxial state of the blood, and that it was this altered state which led to anæsthesia.

Brown-Séquard has shown that in the lower animals certain peripheral stimuli may induce a generalised anæsthetic effect. Thus, by applying electrical excitation to the larynx or its nerves, he was able to bring about a state which he regarded as one of general anæsthesia; and a similar result occurred when a forcible stream of carbonic acid gas was projected into the back of the mouth or into the larynx itself. It is also stated that the local application of chloroform or chloral to certain skin areas of the cat induced generalised effects of a similar nature. These curious phenomena have usually been ascribed to nervous inhibition, brought about by the violent excitation of certain sensory areas; but the subject requires further study before any definite opinion can be expressed concerning it.

It has been shown by Bonwill that it is possible, with certain subjects, to induce a state of analgesia or (?) anæsthesia

[1] *Dict. de Physiologie.*

by the simple expedient of rapid and deep breathing. Dental operations have thus been painlessly performed; but the method has, in other hands, proved uncertain, whilst its *modus operandi* has yet to be established. Some have explained the phenomena by supposing that the exaggerated respiration so modifies the cerebral circulation that the normal activity of the intellectual and perceptive centres becomes temporarily suspended. It is possible, however, that "suggestion" or "inhibition" may play a part in some cases, whilst simple nervous exhaustion may constitute a factor in others.

The analgesic and anæsthetic effects produced by hypnotism hardly admit of discussion in the present work. Experience has shown that only certain susceptible persons can be thus influenced, that a long education is needed to render subjects hypnotisable, and that the general health of those who submit themselves to this treatment is liable to become seriously injured.

Claude Bernard fully realised the occasional presence of an asphyxial element in ordinary cases of chloroformisation, and threw out the suggestion that asphyxia was probably capable of producing anæsthesia of its own—a suggestion which is of interest when considered in the light of more recent research. According to Reboul and Morat,[1] frogs placed *in vacuo*, or in an inert gas, become immobile and insensible; reflex movements disappear; respiration then ceases; but circulation persists for a considerable time. Pure nitrogen rapidly destroys consciousness and produces complete insensibility to pain; and mixtures of this gas with small proportions of oxygen (up to 7 per cent) are similarly capable of inducing anæsthesia, the rapidity of action diminishing as the oxygen percentage rises (see p. 381). It is noteworthy that these results occur when every provision is made for the escape of carbonic acid gas from the lungs, so that we are justified in regarding them as due simply to anoxæmia or want of a sufficiency of oxygen to carry on normal metabolism within the nervous centres. Nitrous oxide produces very similar effects, but they come about with somewhat greater rapidity and are more persistent—a difference doubtless dependent upon the greater solubility of this gas.

[1] Dastre, *op. cit.*

With both nitrogen and nitrous oxide the muscular system is thrown into an epileptiform or tetanic state; and it is this factor which renders these gases irrespirable when administered in a state of purity. The anoxæmic anæsthesia which we see in its typical and pure form in the case of nitrogen and hydrogen is also met with as a by-product, so to speak, when ether, chloroform, or other agents are being employed; and the intensity of the effects produced by these drugs is, in practice, often largely dependent upon the degree of anoxæmia present (see p. 287). In addition, however, to the simple limitation or deprivation of oxygen thus favouring or actually producing general anæsthesia, there is ample proof that, in certain methods of anæsthetisation, in which re-breathing is permitted, the presence of carbonic acid gas (itself an anæsthetic) may contribute to the narcosis.

Claude Bernard contended that anæsthetics brought about within the central nervous system changes which were similar in many respects to those produced either by interference with the blood supply or by commencing natural death. He urged that although there were different means for inducing anæsthesia, they all led to the same modifications in the nerve-cells whatever these modifications might be. He went, indeed, a step further than this, and believed that a process of semi-coagulation took place within the cell-contents of nerve-centres, such semi-coagulation resulting from the direct effects of the anæsthetic brought thither by the circulating blood. Directly elimination of the anæsthetic took place, this coagulative process began to subside, and eventually the cell-contents resumed their normal character. In favour of this theory there was the fact, already alluded to, that muscular tissue, and indeed all protoplasmic matter, quickly becomes cloudy and eventually coagulated when exposed to water containing ether or chloroform in solution. Some observers have found, in animals killed by chloroform, a marked disappearance of fat globules from nerve-cells; and it is pointed out by Meyer and Baum [1] that all bodies nearly chemically indifferent have an anæsthetic action if they are soluble in fat. But considering that nitrous oxide, which has no fat-dissolving properties, pro-

[1] See Dr. Bradbury's paper.

duces effects almost identical in their main features with those produced by chloroform, this hypothesis has little to recommend it. According to Lauder Brunton,[1] chloroform is a powerful solvent of protagon, "the essential ingredient both of the nerve-centres, of the nerves themselves, and of the red blood corpuscles"; but it is very doubtful whether this chemical fact has any important bearing upon the physiology of anæsthetic action. The changes brought about within the nervous elements, whatever they may be, are of a temporary character—they do not permanently affect the structures involved. But beyond this we cannot at present go. It has been suggested that anæsthetics may exert a dehydrating effect upon protoplasm (Dubois' theory); but the grounds for this assumption are too slender to warrant serious consideration. It has been contended, too, that a temporary and dissociable combination is produced between the anæsthetic and the protoplasmic matter with which it comes in contact (Richet[2]); but here again we find nothing but simple speculation to support such a theory. All we can say at the present moment is that, in all probability, some change of a physico-chemical character takes place within the protoplasm of nerve-cells as the result of the presence of anæsthetics within the circulation; that the most delicate and vulnerable of the nervous elements—those which give to the organism its characteristic peculiarities, attributes, and functions—are first affected; and that, finally, the most resistant centres upon which life is dependent are attacked. Whether this change is due to the local effect of the anæsthetic itself upon the cell-contents, or whether some alteration in the blood brought about by the anæsthetic is the immediate cause of such changes, it is at present impossible to say. As is pointed out in many parts of this work, there are remarkable analogies between the effects of simple anoxæmia and those produced by general anæsthetics; and it is not at all improbable that future experimental research may lead us to the conclusion that general anæsthetics produce their characteristic effect by limiting the normal processes of oxidation upon which the intellectual, sensory, and motor centres depend for the execution of their respective functions.

[1] *Therapeutics*, p. 796.

[2] *Dict. de Physiologie*.

CHAPTER IV

THE THEORETICAL AND EXPERIMENTAL PHYSIOLOGY OF GENERAL SURGICAL ANÆSTHESIA (*continued*)

§ 4. THE SPECIAL PHYSIOLOGY OF THE MORE IMPORTANT GENERAL ANÆSTHETICS

A. NITROUS OXIDE

SIR HUMPHRY DAVY believed that nitrous oxide was decomposed into its constituent elements during its passage through the circulation; and the intoxicating effects which the gas produced were hence ascribed to hyper-oxygenation of the blood, whilst the anæsthetic effects were explained on the assumption that the over-production of oxygen led to the formation of such quantities of carbonic acid that "internal asphyxia" arose. It soon became clear, however, that nitrous oxide was too stable a body to be decomposed at the temperature of the blood; and Frankland,[1] who analysed the expiratory products of several administrations, failed to find any distinct evidence of decomposition. In 1864 Hermann[2] came to the conclusion that nitrous oxide was simply absorbed by blood plasma, that it produced no change in blood, and that it was not itself altered during its period of association with blood. Hermann found that 100 volumes of blood at the temperature of the body absorbed somewhat less than 60 volumes of nitrous oxide. Several years later, Bert fixed the solubility at 45 volumes of gas per 100 volumes of blood. The hyper-oxygenation theory was therefore abandoned, and a precisely opposite

[1] *St. Bartholomew's Hospital Reports*, vol. v.
[2] *Brit. Med. Journ.*, 18th April 1868, p. 378.

hypothesis took the field. It was now maintained, and par ticularly by Jolyet, Blanche, and Duret, that the anæstheti effects of nitrous oxide were dependent, not upon excess but upon want of oxygen. It was generally admitted tha many of the phenomena which attended the administration o pure nitrous oxide were asphyxial in their type; and it wa thought highly probable that the same intimate mechanism which gave birth to these phenomena also gave birth to th phenomena of anæsthesia. There were certain consideration which seemed to support this view. Thus, the unconsciousnes was certainly deepest when the asphyxial seizure was at it height, whilst the admixture of air with the anæsthetic ga was believed to disturb or prevent good anæsthesia. But i was soon ascertained that by attention to detail a non-asphyxia form of anæsthesia could be secured by administering air o oxygen with nitrous oxide. Andrews of Chicago was the firs to demonstrate this fact (p. 245). Later on Paul Bert devote much attention to the subject (p. 245), and placed upon scientific basis the truth at which Andrews had arrived. Th French physiologist, however, found that the best results, s far as anæsthesia was concerned, were attainable by increasin the atmospheric pressure at which the two gases were adminis tered (see p. 248); but subsequent experience has shown tha whilst such an increase of pressure undoubtedly has certai advantages, it is by no means essential. Even with mixture containing 20 per cent of oxygen, anæsthesia may be attaine at ordinary atmospheric pressures (p. 246). For further remark on this point I would refer the reader to the chapter dealin with the clinical aspects of nitrous oxide.

It therefore became clear that, whatever the physiologica action of nitrous oxide might be, it certainly possesse anæsthetic properties of its own. As regards the asphyxia phenomena which characterised the action of this gas whe administered free from air or oxygen, these were to be looke upon as accidental, and dependent upon the crude system o administration. It was difficult or impossible to conceiv that asphyxia could play any part in producing anæsthesia if, as was the case, the same quantity of oxygen as that in atmo spheric air could be inhaled with the anæsthetic gas withou

disturbing anæsthesia. We must be careful, however, of our ground as we approach this aspect of the subject. The fact that anæsthesia can be secured by nitrous oxide without producing any *obvious* asphyxial symptoms cannot be held to prove that the anæsthesia of this gas is not dependent upon some alteration in or reduction of the normal oxidation processes taking place within sensory and other nerve-cells. The remarkable influences exerted by increasing and diminishing the percentage of oxygen in nitrous oxide and oxygen mixtures would seem to suggest that there is a very close affinity between the intimate action of nitrous oxide itself upon the central nervous system and the effects of diminishing the normal oxygen supply (see p. 246). It is quite conceivable that the effects of nitrous oxide, ether, and chloroform, when administered with a sufficiency of oxygen to avoid obvious asphyxial (anoxæmic) symptoms, may be the same, and that this action may be of the nature of deoxidation. The initial sensations under nitrous oxide are of an agreeable and stimulant character—almost identical with those of ether and chloroform; and when non-asphyxial and deep nitrous oxide anæsthesia is once established, this anæsthesia is similar in its main features to that produced by other anæsthetics. Were nitrous oxide anæsthesia the result of simple oxygen deprivation we should not expect the initial sensations produced by the inhalation to be of an exhilarating character. Nitrous oxide is, in fact, just as much an anæsthetic as ether or chloroform; the chief differences between them being that nitrous oxide is, in its pure state, respirable only to a certain point, and that (probably in consequence of its physical characters) its toxicity is comparatively feeble.

It has been contended by some observers that the phenomena produced by pure nitrous oxide are one and all special and specific, and that none of them are asphyxial or, more properly speaking, anoxæmic in their nature. This view, however, must now be discarded; for we know that by adding oxygen to nitrous oxide the stertor, the epileptiform movement, and the cyanosis may be prevented without disturbing the anæsthesia. Animals killed by pure nitrous oxide display post-mortem the usual signs of asphyxia, the right cavities of the heart being full, and the left comparatively empty. The

late Sir George Johnson[1] believed that the great difference in the fulness of the right and left chambers was to be ascribed to contraction of the pulmonary arterioles brought about by the non-oxygenated blood. He maintained that, however asphyxia was induced—whether by nitrous oxide, by nitrogen, or by paralysing respiration by curare—the same effects followed. But, as the late Dr. P. Black[2] had previously suggested, it is more probable that the distension of the right heart is consequent upon arrest of respiratory movement. Dr. Black appears to have been the first to put forward this explanation of the characteristic post-mortem appearances of asphyxia. As is elsewhere pointed out in these pages, we have ample evidence in administering anæsthetics of the great dependence of the pulse upon the fulness and efficiency of respiration, and whilst it might be going too far to say that the pulmonary stasis of asphyxia is in no way dependent upon the blood condition, it may be affirmed with certainty that the factor of suspended breathing is one of great importance in preventing the passage of blood from the right to the left cardiac cavities. There are, as we might expect, certain differences between the phenomena produced by nitrous oxide, by nitrogen, and by mechanical closure of the trachea; but they one and all lead to fatal asphyxia. As Sir George Johnson urged (p. 382), there are close resemblances between the effects produced by nitrous oxide and those produced by nitrogen. With each of these gases swelling of the tongue, cyanosis, epileptiform spasm, and deep stertor occur. Although both nitrous oxide and nitrogen are respirable to a certain point, they are irrespirable beyond that point. As originally stated by Jolyet and Blanche, nitrous oxide cannot support animal or vegetable life owing to lack of available oxygen. Germinating seeds cease to germinate in an atmosphere of the pure gas. In the case of man the average inhalation period is about 56 seconds: at the end of that time fresh oxygen must be admitted to the lungs or permanent asphyxia will result (p. 223). That nitrous oxide and oxygen can be

[1] *Brit. Med. Journ.*, 21st and 28th April 1894. The researches of Bradford, Dean, and others appear to render this theory untenable.

[2] See *Brit. Med. Journ.*, 11th March 1876, p. 316.

breathed for a long period without materially interfering with respiration or circulation is shown by a remarkable experiment of M. Claude Martin of Lyons, who administered to a dog a mixture of nitrous oxide with 15 per cent of oxygen for three consecutive days (72 hours).[1]

M. Martin employed a chamber of the capacity of 250 litres, and capable of withstanding an internal pressure of 1·5 atmospheres. Dog put in at 5 P.M. 85 parts of nitrous oxide and 15 of oxygen introduced. Pressure progressively raised to 110, 115, and 120 cm. At 6 P.M. dog well anæsthetised. 25 litres of the mixture supplied every hour. Potash solution used to absorb CO_2. After 12 hrs. respiration calm and remained so until end of experiment. After 72 hrs. dog removed. In 15 min. feet commenced to move and eyes opened. 35 min. later made efforts to stand, and trembled as if cold. After 35 min. he moved paws when pricked, and was able to walk and obey commands. He refused milk. Intelligence apparently unimpaired. At 7 A.M. next morning (14 hrs. after experiment) he was in good spirits, and ate well. The total amount of gas consumed was 2500 litres.

The nature of the blood changes in nitrous oxide anæsthesia is still *sub judice.* There is no definite evidence that this anæsthetic forms any combination with hæmatin or any other constituent of the blood, although some such association is regarded by many as highly probable. As already indicated, nitrous oxide is very soluble in blood.[2] According to Davy, it has the power of turning out oxygen or air from water, and it is probable that in addition to its preventing the access of fresh oxygen to venous blood, it actually dislodges more or less completely that oxygen still remaining in it when it reaches the pulmonary capillaries. As regards the gases present in blood during nitrous oxide anæsthesia little is definitely known. Oliver and Garrett[3] in their experiments found that carbonic acid was present in the blood in small quantities as compared to the amounts met with under other anæsthetics; but in a very large quantity relatively to the amount of oxygen associated with it. In the case of a rabbit the percentages were CO_2 15·66, O 3·49, N_2O 22·49, and N 11·23 per 100 vols. of blood. Kemp has also found a great

[1] See a pamphlet entitled "Sur l'anesthésie prolongée et continue par le mélange de protoxyde d'azote et d'oxygene sous pression (méthode Paul Bert)," by Claude Martin.

[2] See Kemp, *Brit. Med. Journ.*, 20th Nov. 1897, p. 1482.

[3] *Lancet*, 9th Sept. 1893, p. 625.

reduction in the CO_2 of arterial blood. We can hardly be surprised, however, at the diminution in this gas, seeing that during the inhalation of pure nitrous oxide by the ordinary means, the air supply is cut off. The comparatively large percentage of nitrogen in the above analysis is interesting but difficult of explanation, and it is to be hoped that further researches will be conducted to throw light upon this and other peculiar results. Observations are also needed with regard to the blood gases under nitrous oxide and oxygen. Some observers have suggested that by the use of oxygen with nitrous oxide the increased production of CO_2 which would occur might lead to a locking-up of this gas within the blood; but it is difficult to see how this could take place provided all expirations escape, as they certainly do in practice, at the expiratory valve.

The blood-pressure under pure nitrous oxide is markedly raised as shown by Kemp's tracings.[1] This observer points out that the results which he obtained were clearly parallel to those met with in asphyxia, the excursions of the kymographic tracings being more pronounced than with any other anæsthetic. He found, moreover, that there was no depression of the heart until the respiration had become much affected by pushing the anæsthetic. Buxton[2] has attempted to prove by sphygmographic tracings that there is no rise of tension in the human pulse during nitrous oxide anæsthesia, and he uses this fact—which, however, is a doubtful one—as an argument against any analogy between nitrous oxide anæsthesia and asphyxia. But there is little doubt as to the increase in arterial tension. When the usual respiratory embarrassment of deep nitrous oxide anæsthesia takes place there is necessarily a fall of pressure in the systemic arteries owing to impeded pulmonary circulation; but this late fall of tension is hardly to be regarded as directly due to the nitrous oxide, and it is quickly recovered from directly fresh air is admitted to the lungs. Pickering[3] found that after several minutes' action pure nitrous oxide arrested the embryo heart of the chick in diastole; that a mixture of nitrous oxide with 30 per cent of CO_2 rapidly stopped the heart after 30 seconds; but that

[1] *Loc. cit.* [2] *Trans. Odont. Soc.* vol. xviii. [3] *Ibid.*, Dec. 1893, p. 46.

a mixture of 70 per cent of nitrous oxide and 30 per cent of oxygen stimulated the heart, which still acted after several hours' exposure to the mixture. Kemp finds that the heart beats more strongly under nitrous oxide and air than under nitrogen and air, so that the gas may be said to possess a stimulant effect upon the heart.

As regards the effects of nitrous oxide upon the kidney, Kemp [1] states that contraction of the renal vessels takes place, and that urinary secretion rapidly diminishes. He finds that albuminuria is produced, though not to any great extent, in complete narcosis.

When pure nitrous oxide is administered to a lethal degree, respiration ceases, and death takes place from asphyxia, the heart continuing to beat, in some cases for several minutes, after the breathing has ceased. The immediate cause of the respiratory arrest is usually if not always muscular spasm, and not muscular paralysis (see p. 230).

B. ETHER

Ether occupies a position which, so far as its anæsthetic properties are concerned, is in many respects intermediate between nitrous oxide on the one hand and chloroform on the other. It is more potent than the former; less potent than the latter. Waller,[2] basing his conclusions upon the relative effects of ether and chloroform upon isolated nerves, believes that the toxicity of the two anæsthetics is as 1 : 7. The two main characteristics of ether are: firstly, that it is one of the most energetic stimulants known, not only to the circulatory, but to the respiratory, nervous, and glandular systems of the organism; and secondly, that its vapour is, as compared to that of many other anæsthetics, more irritating to the respiratory passages, so that mucus is somewhat freely secreted. Owing to the comparatively feeble toxicity of ether it is necessary, in order to secure deep anæsthesia, to administer its vapour in a concentrated form, or even to add an asphyxial

[1] *New York Med. Journ.*, Nov. 1899.
[2] *Brit. Med. Journ.*, 20th Nov. 1897.

element to the administration; whilst by reason of the low boiling-point of the drug it is quickly eliminated from the circulation when the administration is discontinued. As in the case of nitrous oxide, very powerful effects may be secured by limiting the oxygen supply; and the phenomena of etherisation will, as in the case of the phenomena of nitrous oxide, greatly depend upon the extent to which air is withheld during the inhalation.

The Committee of the Royal Medical and Chirurgical Society (1864) found that ether very slightly depressed cardiac action, and that in ether toxæmia respiration usually ceased before the heart, although the pulse might cease before the respiration. They state that in one case they observed the heart cease before respiration. The "Glasgow Committee" came to the conclusion that when frogs, rabbits, and dogs were anæsthetised by ether and artificial respiration was maintained, the heart continued to beat so long as the experiment lasted. Ringer[1] found that whilst 1 or 2 minims of chloroform arrested the ventricle of the frog's heart, 50 minims of ether merely accelerated and slightly weakened the beats, without interfering with the total quantity of work done. Pickering states[2] that upon the embryonic chick's heart ether produces a powerfully stimulant effect, and that depression only comes about when enormous doses are used.

The Glasgow Committee were unable to satisfy themselves that ether produced any appreciable effect upon blood-pressure. Kemp,[3] in his experiments upon dogs, states that the effect of ether upon general arterial pressure is to raise it from the beginning, even with moderate anæsthesia, and that when the anæsthetic is pushed the pressure rises again slightly. A corresponding fall takes place when the administration is discontinued. In MacWilliam's[4] experiments the blood-pressure usually fell slightly; but there was either no cardiac dilatation or a very slight and transient dilatation, and this was chiefly noticed when ether vapour was given with great suddenness. By

[1] *Practitioner*, vol. xxvi. p. 436.
[2] *Trans. Odont. Soc.*, December 1893, p. 46.
[3] *New York Med. Journ.*, November 1899.
[4] *Brit. Med. Journ.*, 11th October 1890.

administering ether and chloroform alternately to the same animal MacWilliam found a very marked difference so far as cardiac dilatation was concerned. He affirms that ether depresses the vaso-motor centre, causing arterial dilatation and a general but slight fall of pressure.

The Hyderabad Commission found[1] that strong ether vapour caused holding of the breath and slowing of the heart. The Commission failed, however, to produce true anæsthesia with ether unless air were rigidly excluded during the administration—a failure probably due to the high temperature at which the experiments were conducted.

According to Dastre, the temperature falls somewhat more rapidly with ether than with chloroform. As regards the patellar reflex this author states that it persists, in lower animals, even during complete ether anæsthesia.

The action of ether upon blood has yet to be worked out. As already indicated, much will depend upon the system of etherisation adopted. Harley believed[2] that ether was not nearly so powerful as chloroform in diminishing the absorption of oxygen and the elimination of carbonic acid. Von Lerber[3] found that the drug produced practically no effect upon the hæmoglobin of blood, and that in 83 cases in which the urine was spectroscopically examined, there was no increase in urobilin, such as might be expected were the red blood corpuscles disintegrated. On the other hand, Da Costa[4] maintains that ether produces a marked diminution in the hæmoglobin of blood.

As regards the effects of ether upon the kidney, Kemp finds[5] that a special contraction of the renal arterioles is produced, that the flow of urine is lessened, that the secreting cells are damaged, and that albumen appears early in the urine secreted. Buxton and Levy, however, who have repeated the experiments made by Thomson and Kemp, maintain[6] that this "specific" effect is not constant, and that

[1] *Report*, p. 29.
[2] *Transactions Roy. Med. and Chir. Society*, 1864, p. 159.
[3] *Year-Book of Treatment*, 1898, p. 166.
[4] *Ibid.*, 1896, p. 170.
[5] *New York Med. Journ.*, November 1899.
[6] *Brit. Med. Journ.*, 22nd September 1900, p. 833.

it occurs chiefly if not wholly in cases in which the ether has been unduly and unnecessarily pushed.

Dr. Hooper[1] of Boston was the first to draw attention to the fact that whilst stimulation of the recurrent laryngeal nerve during light ether anæsthesia produced adduction of the vocal cords, stimulation during deep etherisation produced abduction. His results have been corroborated by Semon and Horsley,[2] who maintain that ether produces (through the medium of the circulation) a differential action upon the laryngeal muscles themselves. These observers found, in numerous experiments, that the posterior crico-arytænoid muscles lost their electrical excitability long before the adductors, and whilst they do not offer any explanation of the fact, they point out that a difference in the metabolic processes of the abductor and adductor muscles appears to exist.

C. CHLOROFORM

There is perhaps no therapeutic agent whose action has been so frequently and so keenly discussed as chloroform. Possessing, as it does, a higher density and boiling-point than ether, it is not surprising that chloroform exerts a more energetic and less transient effect upon protoplasm than the last-named anæsthetic. We have already referred (p. 75) to Waller's estimate of the relative toxicity of the two drugs. Locally applied, chloroform exerts an irritant or even vesicant effect. Even in dilute aqueous solutions it quickly destroys the irritability and contractility of muscles, rendering them "chloroform-rigid" and producing, microscopically, cloudy and other structural changes (Bernard[3]). According to Brunton,[4] chloroform acts "as a powerful solvent of protagon, the essential ingredient both of the nerve-centres and of the nerves themselves." Subcutaneously injected, it produces a local anæsthetic effect, but owing to its caustic action upon

[1] *Transactions Amer. Laryngolog. Association*, vol. vii.

[2] *Brit. Med. Journ.*, 28th August 1886, p. 405, and 4th September 1886, p. 445—"On an Apparently Peripheral and Differential Action of Ether upon the Laryngeal Muscles."

[3] *Leçons sur les Anesthésiques et sur l'Asphyxie.*

[4] *Therapeutics*, vol. ii. p. 79.

the tissues it passes but slowly into the general circulation, and by reason of free elimination taking place during its passage through the lungs deep anæsthesia is not attainable (Dastre). The application of the drug over large cutaneous surfaces has produced general anæsthesia in animals (Brown-Séquard), but this result has been attributed to inhibition of the nervous mechanism involved in the perception of pain. General anæsthesia may be produced by injecting chloroform into veins.

Snow carefully conducted a series of experiments upon animals with the object of ascertaining the percentages of chloroform vapour needed to produce the various "degrees of narcotism" (p. 60), which he described; and he also roughly calculated the actual quantity of chloroform which was present in the blood at various stages in the administration. He arrived at the conclusion that one grain of chloroform to each 100 cubic inches of air sufficed to induce his "second degree of narcotism," the fraction $\frac{1}{56}$ expressing the degree of saturation of the air from which the vapour was immediately absorbed into the blood, and consequently also the degree of saturation of the blood itself. He further found that two grains of chloroform to each 100 cubic inches of inspired air caused a state of very complete insensibility, corresponding with his "fourth degree of narcotism"; and the fraction $\frac{1}{28}$ expressed the extent of saturation of the blood in this degree. As regards quantities of chloroform exceeding two grains to 100 cubic inches of air, these had a tendency to embarrass and arrest the function of respiration, provided that the inhalation were continued; and he calculated that three grains of chloroform to each 100 cubic inches of air was very nearly the quantity which had the power of arresting the breathing when the temperature of the body was 100°, the fraction $\frac{1}{18}$ or $\frac{1}{19}$ representing the blood saturation in this toxic state. Snow also calculated that for his second degree of narcotism it was necessary that the blood of an average adult patient should contain about 12 minims; for the third degree, 18 minims; for the fourth degree, 24 minims; and for the arrest of respiration about 36 minims. Pohl[1] found

[1] *Taylor's Jurisprudence*, 4th edit. p. 425.

that the blood of a dog deeply under chloroform contained from ·01 to ·06 per cent of chloroform, the average amount being ·035 per cent; and that the red corpuscles contained about two and a half times more than the serum.

The Royal Medical and Chirurgical Committee found that with atmospheres containing from 2 to 4 per cent of chloroform vapour there was little or no risk to life; but that in some cases it was necessary to employ an atmosphere containing as much as 5 per cent of vapour. Stronger atmospheres induced alarming symptoms.

Paul Bert's results were similar to those obtained by Snow. With 4 grammes of chloroform to 100 litres of air insensibility was not produced, but the animal died at the end of 9 or 10 hours with a low temperature. With 6 grammes to 100 litres a diminution of sensibility was noted, and the animal died at the end of 6 or 7 hours. With 8 grammes to 100 litres insensibility was slowly produced, and death took place in 4 hours. With 10 grammes to 100 litres [1] anæsthesia was obtained in a few minutes, and death took place in 2 or 3 hours. With 12 grammes to 100 litres the animal died in rather less than 2 hours. With 15 grammes to 100 litres death occurred in 40 minutes; with 20 grammes to 100 litres in 30 minutes; with 30 grammes to 100 litres in 3 minutes. As Dastre points out, it is interesting that weak chloroform atmospheres affected nutrition without destroying sensibility.

Waller's [2] observations as to the effects of different percentages of chloroform vapour upon the electromobility of isolated nerves have led him to the conclusion that this anæsthetic is about seven times as powerful as ether.

As already pointed out (p. 42), the respiratory phenomena which attend the administration of an anæsthetic will be found to depend upon numerous other factors than the special action of that anæsthetic upon the nervous mechanism of breathing. The great tendency in man for mechanically obstructed breathing to arise under chloroform, and to set up an unexpected and perhaps unrecognised asphyxial state, doubtless explains

[1] This mixture is roughly equivalent to a 2 per cent mixture of chloroform vapour and air.

[2] *Brit. Med. Journ.*, 20th November 1897, p. 1469.

many, and perhaps most of the chloroform accidents of practice. In the physiological laboratory, where artificial respiration is generally maintained during chloroform administration, the importance of this intercurrent asphyxial factor is perhaps insufficiently realised. Under the influence of chloroform the respiratory centre is at first stimulated—the stimulant effect varying according to the circumstances present; it is then depressed; and it finally becomes paralysed.

Whether or not the toxic respiratory failure met with in the lower animals is ever associated with an obstructive element such as is undoubtedly sometimes present in man when chloroform is given in poisonous doses has not to my knowledge been determined.[1] Owing to the vapour of chloroform being less irritating than that of ether, the breathing under the former anæsthetic is less liable to be interrupted by "holding the breath" and obstructive spasm than the breathing under the latter. At the same time it must be remembered, as originally pointed out by Claude Bernard and the Committee of the Royal Medical and Chirurgical Society, that if chloroform be given in a concentrated form, intercurrent asphyxial complications will be at once introduced, and free breathing more or less completely suspended owing to reflex closure of the larynx. This reflex suspension of breathing, however, does not appear to be dangerous in the case of lower animals even though associated, as it often is, with temporary cardiac inhibition. The principal risk in a concentrated vapour is that of simple toxæmia. When chloroform narcosis is well established the breathing is somewhat quieter, slower, less forcible, and of less amplitude than that of ether narcosis. Paul Bert,[2] in his experiments upon dogs, found that costal breathing became gradually less marked, and that eventually most of the respiratory work was carried on by the diaphragm. If diaphragmatic breathing were paralysed by section of the phrenics, costal breathing began. As regards the expansive force of respiration, this is diminished in proportion to the degree of narcosis. Thus, Dastre found, in the case of a dog of 12 kilos. 850 grammes, whose respira-

[1] Since writing this chapter, Dr. Leonard Hill has informed me that he has frequently noted this association in dogs and cats.

[2] Dastre, *op. cit.*

tion became arrested by a weight of 75 kilos. when no anæsthetic was administered, that respiratory arrest during anæsthesia occurred with a weight of but 58, 55, or 25 kilos., according to the duration of the insensibility. The same author states that the experiments of Langlois and Richet led these observers to the conclusion that, during anæsthesia, expiration was considerably more depressed than inspiration. The inspiratory efforts of an anæsthetised dog were not much modified by anæsthesia; but there was a considerable reduction in the expiratory force. As regards the immediate causation of respiratory failure in chloroform toxæmia, there is good evidence that, in addition to the factor of the anæsthetic itself acting upon the nervous mechanism of breathing, and bringing about respiratory paralysis, there is often another factor present, viz. the low arterial tension caused by the cardiac depression. The Glasgow Committee came to this conclusion[1] many years ago; and Leonard Hill's recent researches have corroborated their views. The accompanying tracing, kindly lent me by the last-named observer, is interesting in this connection.

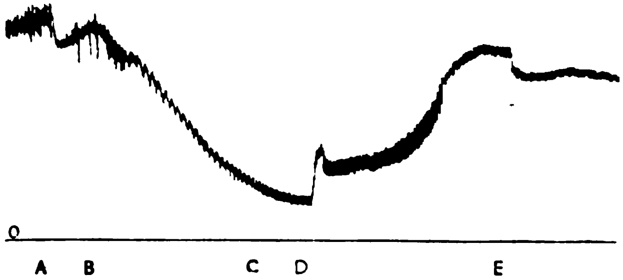


FIG. 1.—Tracing 1. (Published in the *Journal of Physiology* in Paper 1—"On the Influence of Gravity on the Circulation.") Cannula in carotid placed in axis of rotation. Dog. Morphia. At the bottom of the fall produced by chloroform the respiratory waves disappear. On turning the animal feet-up the blood pressure rises and the respiratory waves immediately reappear on the trace. This shows that paralysis of the respiratory centre is partly due to fall of arterial pressure. A, Feet-down: vertical posture. B, Chloroform pushed. C, Withdrawn. D, Feet-up posture. E, Horizontal.

Hill maintains that the tracings of the Hyderabad Chloroform Commission also conclusively prove that circulatory failure may itself lead to respiratory arrest.

[1] *Brit. Med. Journ.*, 18th December 1880.

Salivation is generally somewhat increased during the early stages of chloroformisation, and diminished during deep anæsthesia. According to Dastre, the chorda tympani retains its excito-secretory action throughout, whilst the reflex action of the lingual nerve on the submaxillary gland is lost soon after the corneal reflex disappears.

As regards the respiratory exchanges under chloroform, Arloing[1] found that less oxygen was absorbed and less carbonic acid exhaled than under normal circumstances, but that the diminution was most marked in the case of the latter gas. Paul Bert's experiments led him to the same conclusion. Thus[2] in one experiment he found that before anæsthesia the absorption of oxygen was 9·9 litres per hour; and the production of CO_2 9·55 litres. Five minutes after the cornea had become insensitive the results were: Oxygen 6·57; CO_2 5·26. After 45 minutes' anæsthesia the figures were: Oxygen 4·42; CO_2 3·39. And after 90 minutes' anæsthesia: Oxygen 3·69, and CO_2 2·39. It will be seen from these figures that there was a progressively greater diminution in the CO_2 excreted than in the oxygen absorbed, the difference representing diminished tissue change and metabolism during chloroformisation. As we have already seen (p. 60), the results at which Rumpf arrived were similar to those of Paul Bert. The Glasgow Committee, however, came to the conclusion that an *increased* amount of CO_2 was exhaled during chloroform anæsthesia. The effects of anæsthetics upon the heat-regulating mechanisms of the organism have been already referred to.

The blood changes induced by chloroformisation have not as yet been satisfactorily determined. We have already pointed out (p. 42) that during the inhalation of this and other anæsthetics respiration is necessarily greatly modified independently of the action of the anæsthetic itself upon the nervous mechanism of breathing, and it therefore follows that the blood changes of chloroform anæsthesia must depend not only upon the composition of the atmosphere presented to the lungs, but upon the rate and depth of breathing, the presence or absence of any obstruction to the entrance of air or the

[1] Dastre, *op. cit.* [2] Dastre, *op. cit.*

exit of carbonic acid, and other circumstances. George Harley[1] believed that chloroform diminished the power of the constituents of the blood to unite with oxygen and to give off carbonic acid, and other observers[2] have endorsed his views. He described various degrees of disintegration of the red blood cells as referable to the action of chloroform, and corroborative evidence in the same direction has been advanced by Ostertag, McKendrick, Sansom, Wittich, and Bötticher.[3] McKendrick,[4] Coats, and Newman, studying the effects of the inhalation of chloroform on the pulmonary circulation of the frog, describe: (1) retardation and then stoppage of the circulation; (2) indistinctness of individual epithelial cells of alveoli and disappearance of their nuclei; (3) contraction in calibre of arterioles and capillaries; and (4) disintegration of corpuscles.

Little is definitely known concerning the gases of the blood in chloroform anæsthesia. Bert, in his experiments with his "Mélanges titrés," found that as regards the blood, as the administration proceeded, a progressive diminution in the quantity of oxygen and an increase in that of carbonic acid took place. In the case of his 12 : 100 mixture (*vide supra*) the following were the figures:—

Before Anæsthesia.		After 30 minutes' Anæsthesia.	
O	22	O	16·8
CO_2	31·2	CO_2	41·2

An hour later he found:—

O	14
CO_2	44

Similar results have been obtained by De St. Martin.[5]

This observer found the blood gases of a dog, before chloroform was administered, to be as follows:—

[1] *Transactions Roy. Med. Chir. Soc.*, 1864, p. 159.
[2] *E.g.* Oliver and Garrett, *Lancet*, 9th Sept. 1893.
[3] I am indebted for this and other statements on this subject to Dr. Guthrie's excellent article in the *Clin. Journ.*, 24th March 1897.
[4] *Brit. Med. Journ.*, Dec. 1880.
[5] *Recherches expérimentales sur la Respiration*, p. 189. Quoted by Oliver and Garrett, *Lancet*, 9th Sept. 1893.

O	15·20
CO_2	40·85
N	2·45
	58·50

The observation was made at 9.50 A.M. Five minutes later the inhalation of a 10 per cent chloroform atmosphere was begun. At 10.7 A.M. the animal was asleep, and at 10.10 A.M. the blood contained :—

O	15·05
CO_2	36·40
N	2·85
	54·30

The administration was continued, and half an hour later a further analysis gave :—

O	12·88
CO_2	50·62
N	3·05
	66·55

As regards venous blood, Paul Bert found that the oxygen again showed diminution but the CO_2 remained about stationary. The preliminary researches of Oliver and Garrett[1] give the following figures :—

Dog. Arterial Blood. Chloroform Anæsthesia

CO_2	37·21
O	17·09
N	8·03
$CHCl_3$	0·02

Rabbit. Arterial Blood. Chloroform Anæsthesia

	(A)	(B)	(L)
CO_2	6·46	19·33	24·85
O	20·96	16·86	13·14
N	54·72	38·33	13·7
$CHCl_3$		4·55	2·59

[1] *Loc. cit.*

Rabbit. Chloroform and Oxygen

	(M)	(N)	(O)	(P)	(U)
CO_2	45·18	58·43	37·26	26·38	35·96
O	21·02	16·06	22·95	19·03	16·83
N	8·96	11·56	11·65	8·92	6·62
$CHCl_3$	1·18	1·20	0·62	1·5	trace

The most curious feature in the above figures is the large proportion of nitrogen. Further research is necessary before these results can be discussed.

The effects of chloroform on blood-pressure have received considerable attention. The Committee of the Royal Medical and Chirurgical Society found a primary rise in arterial tension and then a fall, the rise corresponding in many cases to struggling and forcible expiratory efforts, although in some instances there was a slight initial rise even when no struggling occurred. The Glasgow Committee met with a pronounced fall of pressure in all their experiments, and attributed this fall, in some cases at least, to a direct effect of chloroform upon the heart. According to the Hyderabad Chloroform Commission, the characteristic fall of pressure—that which occurs with regular breathing—is due not to weakening of the heart, but "solely to narcosis of the vasomotor system, and is, if not a safeguard, absolutely harmless."[1] The sudden fall in pressure observed by the Glasgow Committee was regarded by the Hyderabad Commission as due to intercurrent asphyxia. MacWilliam found an initial temporary rise of pressure in some cases. With regard to the subsequent fall, this he believed to be primarily due to vasomotor depression, but secondarily to cardiac dilatation. He pointed out that blood-pressure tracings alone were unsafe guides as to the strength and character of the heart's action or even of the ventricular beats. He found that a weak ventricular beat might cause a large oscillation in the blood-pressure trace and *vice versa.* He also drew attention to the fact that a great increase in the rapidity of the heart's action might occur without inducing any noticeable rise in blood-pressure. According to Wood and Hare,[2] chloroform produces

[1] *Report*, p. 137.

[2] *Med. News*, 22nd February 1890.

a double initial effect upon the blood-pressure—first a fall due to reflex inhibition of the heart or vaso-motor centre, and then a rise, due probably to reflex vaso-motor spasm. They agree with other observers that this reflex inhibitory cardiac arrest is never permanent (*vide infra*). Gaskell and Shore found an initial rise and subsequent fall of pressure, the former being due, according to them, to a stimulation of the vaso-motor centre. As regards the causation of the subsequent fall, these observers found, as the result of a series of ingenious cross-circulation experiments,[1] that it was principally due to an effect of chloroform upon the heart, and not, as the Hyderabad Commission had stated, to an effect upon the vaso-motor centre. They were led to the conclusion, indeed, that chloroform stimulated rather than depressed this centre; for they found that injections of the drug into the cerebral arteries caused a *rise* in pressure which was still present at the moment when respiration ceased. They further found that in other conditions—for example, when the brain arteries were ligatured, when amyl nitrite was injected into the cerebral vessels, and when the intracranial pressure was raised—the respiratory centre failed *before* the vaso-motor centre. It is, in fact, now generally agreed that the fall of pressure under chloroform is chiefly dependent upon effects produced by chloroform upon the heart itself. According to the Hyderabad Commission, and to MacWilliam, the low pressure is, in a sense, protective, for it tends to prevent the absorption of fresh chloroform by the pulmonary blood-stream. Bradford finds that during chloroformisation the pressure in the pulmonary artery falls like the pressure elsewhere, so that there is no good evidence in favour of any special contraction of the pulmonary arterioles. This observer, indeed, working in conjunction with Dean, found only a feeble vaso-motor mechanism in the pulmonary vessels, and Fr. Franck's researches corroborate this view (Hill).

This naturally brings us face to face with the question, What evidence have we as to the direct effect of chloroform upon the heart? Snow's observations led him to the conclusion that *primary* cardiac paralysis only took place with high

[1] *Brit. Med. Journ.*, 21st January 1893.

percentages of vapour, and that, provided precautions were taken to avoid such concentration, the heart only failed secondarily to the breathing. In the case of cats, chloroform atmospheres of 3 per cent to 6 per cent caused stoppage of breathing before arrest of the heart—an interval of two or three minutes separating the cessation of respiratory and cardiac action in many cases. But with atmospheres of 8 per cent to 10 per cent "the action of the heart was always seriously affected and rendered extremely feeble, if it did not actually cease, at the time the breathing was arrested." The experiments of the Committee of the Royal Medical and Chirurgical Society also pointed in the same direction. The Committee found that the strongest doses of chloroform destroyed animal life by arresting the action of the heart, and that moderate doses considerably weakened cardiac action before death ensued, although respiration generally ceased before the heart's action completely failed. The strongest doses of chloroform caused the pulse and respiration to cease nearly simultaneously (in from 1′ 20″ to 1′ 45″), whilst the heart's action continued for a short time subsequently (from 3′ 10″ to 5′ 30″); but when equally strong atmospheres were administered through an opening below the glottis, death was much more rapid, "and the heart, as a rule, ceased to beat several seconds before the final arrest of the respiratory movements." With moderately strong and weak vapours little or no difference was observed whether the chloroform entered above or below the glottis. The Committee found that a strong chloroform vapour did not cause a more permanent stoppage of the heart's action than a milder vapour. Some years later (1879-80) the Glasgow Committee arrived at very similar conclusions. Not only did they find that in the dog, rabbit, and frog cardiac action soon ceased under chloroform—far sooner than under ether [1]—but they came to the conclusion that chloroform sometimes exerted an unexpected and capricious action on the heart, causing a rapid fall of pressure—a conclusion which was subsequently challenged and criticised by the Hyderabad Commission, who regarded the tracing upon which the Glasgow Committee had based their views as indicating an

[1] *Brit. Med. Journ.* vol. i., 1879, p. 1.

asphyxial element in the administration. Ringer, however, clearly showed[1] that so far as the frog's heart was concerned chloroform undoubtedly produced a powerfully depressant effect upon the muscular tissue itself, one or two minims of the drug sufficing to arrest ventricular action. The Hyderabad Commission attempted to prove by a very large number of observations that during the administration of chloroform the heart was never primarily affected—in other words, that its action was maintained till respiration had ceased; but, as we have already pointed out (p. 17), these observations have not been accepted by the physiological world. The much-disputed point whether chloroform has or has not a directly depressing effect upon the heart must, in fact, now be regarded as settled in the affirmative. It would, indeed, be extraordinary were this anæsthetic, with its undoubtedly high toxicity as regards muscular tissue, to specially spare the fibres of the cardiac walls. MacWilliam was the first physiologist to supply the missing link which was required to complete the chain of evidence against chloroform. This observer showed that a varying degree of dilatation of the heart's cavities took place, the dilatation commonly commencing when corneal reflex disappeared. All chambers shared in the dilatation, and when the anæsthetic was lessened the dilatation usually disappeared. In some cases the dilatation was rather sudden, and it was as a rule independent of rate. When the dilatation was extreme the heart failed, although rhythmic movements persisted for a while. MacWilliam further found that the cardiac dilatation was not due to fall of pressure, nor was it dependent upon increased pulmonary resistance from vascular contraction. It was, in fact, due to the effect of chloroform on the cardiac mechanism itself. He observed, in some cases, periodic cardiac dilatation *after* chloroform, and found that ether dispelled this. Whilst agreeing with the Hyderabad Commission that the characteristic fall of blood-pressure under chloroform was *primarily* due to the depressing influence of the drug on the vaso-motor centre, he maintained that cardiac dilatation was the chief factor. Usually dilatation did not come on till after blood-pressure had fallen, though it might

[1] *Practitioner*, vol. xxvi. p. 436.

do so. In some cases MacWilliam found a state of "delirium cordis"—the ventricle being thrown into a condition of inco-ordinated fibrillar contractions. Gaskell's and Shore's experiments[1] also led them to the conclusion that chloroform exerted a direct paralysing influence upon the heart and blood-vessels; and they pointed out that the so-called proof that chloroform does not affect the heart, which was afforded by the Hyderabad Commission tracings, was in every case an instance of a slight increase in the size of the pulse-excursions due to a slowing of the heart's action. Wood and Hare[2] also agree that chloroform has a direct effect upon the heart itself. Moreover, experimenting with the embryonic heart of the chick—*i.e.* with a heart not yet supplied with any nervous mechanism—Pickering[3] has found that ·5 c.c. of a chloroform solution containing ·00003 c.c. of pure chloroform will, if injected under the blastoderm of the embryo, rapidly reduce its cardiac rhythm and produce an exaggerated diastole. After the injection of ·00004 c.c. the heart stopped in a dilated condition. He found a mixture of CO_2 and chloroform to be far more toxic to the embryonic heart than a mixture of chloroform and air. But the final and most complete proof of the error of the Hyderabad doctrine has been brought forward by Leonard Hill, who has shown that the methods employed by the Commission for registering the efficiency of cardiac contraction were faulty. Hill has corroborated MacWilliam's original observations as to chloroform producing paralytic dilatation of the heart. He finds that it acts directly, like amyl nitrite, on the musculature of the whole vascular system. He very properly lays stress upon a point which is fully discussed in the clinical part of this work, viz. that the real question is when the heart *ceases to expel its blood*—not when it ceases to make *efforts at contraction*. If a dog be killed by a concentrated chloroform vapour, respiration will usually continue longer than the femoral pulse; and if the chest be opened, the heart will be found much dilated and exhibiting waves of contraction although unable to empty its cavities.

[1] *Brit. Med. Journ.*, 28th Jan. 1893.
[2] *Medical News* (Phila.), 22nd Feb. 1890.
[3] *Trans. Odont. Soc.* vol. xxvi. No. 2, N.S., Dec. 1893, p. 42.

These waves, in fact, are ineffectual in maintaining a circulation—the heart having failed to act *as a circulating organ*. In the course of an important research, Hill and Barnard made some experiments, the results of which coincided with those previously obtained by Gaskell and Shore, and they point out,[1] in connection with the cardiac dilatation which occurs under chloroform, that the power required to empty the cardiac cavities may be regarded as increasing approximately as the cube of their radius. To sum up, then, on this much-disputed point, it may be regarded as established that during chloroform anæsthesia this anæsthetic directly produces a depressing effect upon the heart itself; and that whilst it is true, not only in the physiological laboratory but in actual practice, that respiration generally ceases before cardiac action finally fails (p. 354), it is the want of cardiac action which is the essential factor in the causation of death under chloroform.

It is now generally admitted that the reflex cardiac inhibition which may be brought about in the lower animals by the direct effect of chloroform vapour upon the sensory nerve-endings within the upper air-passages is not of itself dangerous; and the same is apparently true with regard to traumatic and other stimuli applied directly to the vagus itself. Dastre and numerous French physiologists have, however, attached great weight to these temporary inhibitory effects, and have even gone so far as to speak of a "syncope laryngo-réflexe." According to Dastre, Franck found that excitation of the laryngeal nerves more easily arrested the heart during chloroform anæsthesia than when no anæsthesia was present; but so far as I am aware this observation has not been corroborated. Later physiology has rather tended to show that the low tension brought about by temporary cardiac inhibition is, in a sense, protective, death being found to take place rather more rapidly when the vagi are divided or when atropine has been given than when the pressure is reduced through the agency of an intact inhibitory mechanism (Richet). The Hyderabad Commission found that it was impossible to kill animals by operative procedures or direct vagal irritation, no matter whether the anæsthesia were light or profound. By inducing

[1] *Brit. Med. Journ.*, 20th Nov. 1897, p. 1496.

repeated and prolonged vagal arrest of the heart, however, Leonard Hill has succeeded in bringing about a fatal issue, the low blood-pressure leading to paralysis of the respiratory centre and death by asphyxia. Still, it may be said that, speaking generally, inhibitory cardiac effects are not as a rule liable to be attended by fatal results.

The effects produced by injecting chloroform into the large veins have been much discussed. The Hyderabad Chloroform Commission obtained only the usual phenomena of anæsthesia. The comparatively negative results, however, which were obtained by the Commission were doubtless due, as pointed out by Gaskell, Shore, and Leonard Hill, to the faulty method which they employed—a method which prevented the chloroform mixing with the venous blood and passing into the heart cavities. Gaskell, Shore, Hare, Thornton, and Leonard Hill all agree as to the depressing effect which chloroform produces upon the heart when the drug is thus introduced into the circulation. The last-named physiologist finds that if 1·5 min. of chloroform be injected into the jugular vein and washed in with saline fluid, a brief stimulant effect is produced which is followed by a diminution in the output of the systole and slight dilatation; whilst 5 mins. have the effect of instantly producing profound dilatation and feebleness of action. The tracing of Fig. 2 clearly shows these effects.[1]

Injections of chloroform into the carotid arteries cause, according to Gaskell and Shore, cessation of breathing from paralysis of the respiratory centre and sudden fall of blood-pressure from paralysis of the vaso-motor centre. That the latter centre was paralysed would seem to be evident from the fact that the cessation of breathing was not followed by any asphyxial rise of pressure; nor did the stimulation of a sensory nerve have any effect in raising pressure.

We are indebted to Leonard Hill[2] for many valuable researches upon the circulation during chloroform anæsthesia. He has shown that this anæsthetic rapidly abolishes the vascular mechanisms which compensate for the hydrostatic

[1] This tracing appeared in the *Brit. Med. Journ.*, 20th November 1897, p. 1497, and it is reproduced here by kind permission of Dr. Hill.

[2] *Brit. Med. Journ.*, 17th April 1897, p. 959.

effect of gravity. Thus, when the body of a chloroformed animal is brought from the horizontal to the feet-down position, there is a far greater fall of arterial pressure than occurs in the absence of chloroform anæsthesia. The principal effect seems to be due to a paralytic state of the splanchnic vasomotor mechanism leading to an accumulation of blood within the splanchnic area; but the failure of the respiratory pump is also an important factor. The deeper the anæsthesia the

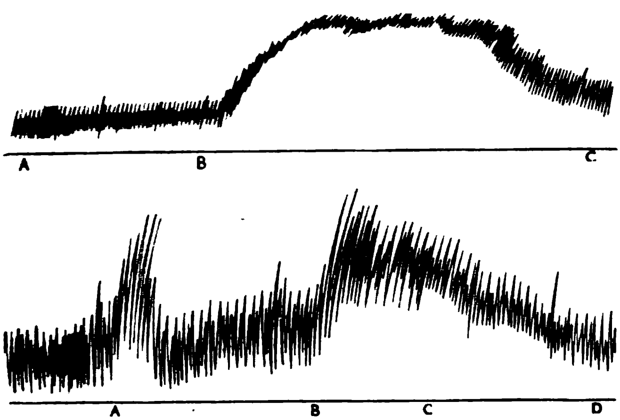


FIG. 2.—Tracing 2. Heart enclosed in tennis ball connected with piston recorder. Record of diastolic and systolic volume. Upper tracing: A, 1·5 min. of chloroform injected into jugular vein. B, 5 mins. injected. Great diastolic distension shown by rise of base line and small systolic strokes. Paralytic distension of heart. C, Heart recovered from distension. In other experiments 5 mins. proved fatal. Lower tracing: A, 5 mins. of ether injected into jugular. Increased systolic stroke and little diastolic distension. B, 4 mins. A.C.E. injected. Initial ether effect followed by chloroform effect. C, Stimulation of ether and alcohol passed off. D, Heart recovered from distension.

greater is the damaging effect of the drug upon the vasomotor controlling mechanism. The importance of Hill's researches is obvious in relation to the posture of patients during chloroformisation (pp. 141 and 476). The tracings[1] shown on the next page exemplify the various points to which reference has been made.

Chloroform has decidedly less effect than ether upon the renal functions. Thomson and Kemp found, in some recent experiments, that the urinary secretion remained copious, only

[1] These tracings, for which I am indebted to Dr. Leonard Hill, are here published for the first time.

diminishing when the general circulation became depressed; that albumen only appeared after prolonged narcosis, and then

FIG. 3.—Tracing 3. Aortic pressure. Cannula in carotid, placed in axis of rotation. Dog. Morphia. The normal effect of the vertical feet-down (head-up) and feet-up (head-down) position. A, Feet down. B, Horizontal. C, Feet up. D, Horizontal. At E the tracheal tube was inserted into a bottle containing chloroform, and the animal was placed in the vertical position. The tracheal tube was removed when the fall became precipitous. F, Abdomen compressed. G, Horizontal. At H feet down and tracheal tube placed in ether bottle. The tracing shows that chloroform more rapidly abolishes the mechanism which maintains the carotid pressure in the vertical posture, viz. tone of arteries, tone of skeletal muscles, and action of respiratory pump. I, Abdomen compressed. J, Horizontal.

in but small amount; and that, so far as oncometric tracings were concerned, these corresponded with the carotid tracings

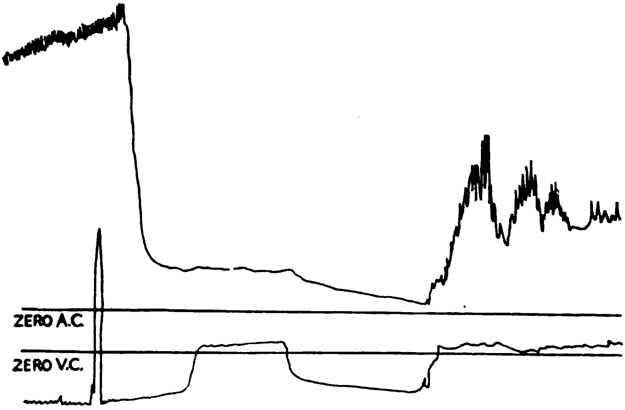


FIG. 4.—Tracing 4. Rabbit. Vena cava and aortic pressures. Cannulæ in superior vena cava and carotid, placed in axis of rotation. Animal in vertical feet-down posture. A, 2 mins. of chloroform injected into vena cava. B, Animal immersed in bath up to level of heart. Hydrostatic pressure of water outside normally balances that of blood inside, and restores aortic pressure if fall be due to vaso-dilatation and loss of muscular tone, *e.g.* after section of dorsal cord. In this case vena cava pressure is raised, but aortic pressure is not, for heart is in paralytic dilatation. D, Artificial respiration. Circulation mechanically sustained. This was ineffectual in this experiment in recovering the heart.

and never fell to the base line, as did those obtained when employing ether (p. 77). The results obtained by Buxton

and Levy in a later research agree in the main with those of Thomson and Kemp.

The repeated administration of chloroform over a period of several days produces, in the lower animals, certain pathological changes to which attention has been directed by Ostertag, Ungar, Strassman, Thiem, Fischer, Kast, and Mester. Amongst these changes the most conspicuous are fatty degeneration of various organs, especially fatty infiltration of the liver, and fatty metamorphosis of the cardiac and skeletal muscles, kidneys, and stomach.[1] It is believed that these changes are dependent upon the action of chloroform itself upon the blood and tissues (see p. 84). Paul Bert, using his 10 : 100 mixture (see p. 80), subjected a dog to daily chloroformisation for thirty-two days, at the end of which time the animal died. He found that the time required to induce anæsthesia did not increase or decrease, but the stage of excitement became less and less marked. The elimination of urea was increased. The urine never contained albumen, sugar, or chloroform. From the twelfth to the thirty-second day the animal was lethargic. At the post-mortem the cellular tissues were found to have lost their fat; the muscles were atrophied and pale; and the liver was fatty.

With the foregoing data at our disposal we are in a position to commence the consideration of the question, How does chloroform kill? Owing to the fact that the experimental physiologist cannot reproduce many of the clinical phenomena which play such an important rôle in the chloroform accidents of practice, we shall not be in a position to complete the consideration of this question till we have studied the nature and origin of these clinical phenomena (see p. 338). The physiological facts which we have embodied in the preceding portions of this chapter merely give us an insight into the mechanism of death from chloroform toxæmia. But, as we shall subsequently see, many, and perhaps most, of the chloroform accidents of practice take place not from an overdose of the drug, but from some intercurrent and often unrecognised asphyxial state, which, in conjunction with the

[1] For further information, see an interesting paper by Dr. L. Guthrie, *Lancet*, 27th January 1894, p. 193, and 3rd February 1894, p. 257, from which I have freely quoted. See also p. 368.

presence of chloroform within the circulation, quickly leads t fatal cardiac paralysis. So far as we have gone, then, it woul seem that we have in chloroform a drug which, when given i toxic quantities, leads to death of the organism, not because i paralyses respiration—for were it merely a respiratory de pressant artificial respiration would be invariably successful i averting death—but because, as recent researches have shown it primarily and markedly depresses the heart, and it is thi cardiac depression which renders it difficult to resuscitat patients. The fact that an overdose of chloroform generall paralyses respiration before the heart's action finally cease must not be allowed to overshadow the more important fac that prior to and during the respiratory failure the hear has, in many cases, ceased to circulate blood through the organism.

The ingenious theory advanced by Brunton to account fo deaths early in chloroformisation must here be referred to although there is little if anything to support it. He believes that in partially established anæsthesia the vaso-motor centre may be paralysed whilst the cardio-inhibitory centre is still intact, so that an operation begun at this juncture may have the effect of causing cardiac inhibition without at the same time inducing that contraction of the arterioles which is generally regarded as necessary in preventing the too rapid emptying of the heart which would otherwise take place. In complete anæsthesia, on the other hand, as the cardio-inhibitory centre is paralysed, no such cardiac arrest is possible. This theory, however, must now be discarded; for not only is it clear, from what has been said, that the vaso-motor centre retains its functions till the later stages of chloroformisation, but there is ample evidence, both experimental and clinical, to show that in all stages of anæsthesia cardiac inhibition may be induced (p. 143).

Other ingenious and complex theories have also been evolved to explain early chloroform syncope. Thus Dastre not only speaks of the primary or laryngo-reflex syncope above-mentioned, but he accepts Duret's hypothesis of an early "bulbar syncope" which is supposed to result from a very strong vapour stimulating and then paralysing the cardio-acclerator centre of the cervico-dorsal cord, whilst the cardio-inhibitory centre is in a state of excitement and brings the heart to

standstill. There is excited cardiac action; the blood-pressure, raised at first, quickly falls because the heart-beats lose in force what they gain in rate; the heart then slows and finally ceases, the slowing being due to paralysis of the accelerator centres of the cord, and the syncope to a direct and excitant action of the chloroform upon the inhibitory mechanism. More recent research, however, has tended to show that deaths early in chloroform anæsthesia are due to causes which have not as yet been studied experimentally (see pp. 342 *et seq.*).

The accompanying tracing (kindly presented to me by Dr. Hill) is of interest in connection with the application of remedial measures in chloroform syncope.

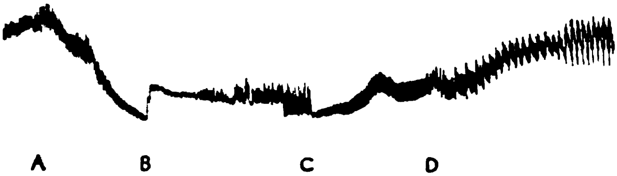


FIG. 5.—Tracing 5. Cannula in carotid. Dog. Shows recovery from chloroform syncope brought about by rhythmic compression of thorax in horizontal posture. Abdomen was now and again gently compressed to fill heart. Shows that respiratory waves disappear as arterial pressure falls (A–B), and that natural breathing reappears when the arterial pressure becomes raised during the period of asphyxia (C–D) which follows after the period of artificial respiration (B–C). Also shows how the arterial pressure can be mechanically maintained by artificial respiration. Blood is forced into the right heart and lungs by abdominal compression, and driven through lungs and left heart into aorta by thoracic compression. A, Chloroform pushed. B, Artificial respiration: alternate compression of abdomen and thorax. C, Artificial respiration left off, followed by asphyxial rise. D, Commencement of natural breathing.

D. OTHER AGENTS CAPABLE OF PRODUCING GENERAL ANÆSTHESIA

Comparatively few researches have been conducted with the other general anæsthetics to which incidental reference has already been made (p. 38); and the reader will therefore find in the clinical sections of this work (pp. 372 *et seq.*) most of the information which is at the present time available concerning the action of these substances. There are, however, certain theoretical and experimental data which call for brief notice in the present chapter.

Little is definitely known as to the physiological action of **bromide of ethyl**. According to Dastre, Rabuteau found that,

like other anæsthetics, it arrested germination, but that its vapour was more poisonous to plants than that of ether. Dastre states, moreover, that whilst the bromide is undoubtedly a powerful anæsthetic, it does not, like chloroform, lead to "primary syncope," and he believes that this difference is due to the drug being less irritating and caustic in its local action (see p. 34). He explains the usual absence of excitement by the supposition that the cerebral hemispheres, bulb, and cord are peculiarly sensitive to the action of the drug. The effects produced upon blood-pressure by bromide of ethyl have not as yet been satisfactorily determined.

Ethidene dichloride was experimentally studied by the Glasgow Committee,[1] who found that under its influence blood-pressure fell, though not to the same extent as in the case of chloroform. They found, moreover, that it had not nearly such a depressant action upon the heart as chloroform, so that it might be considered a safer anæsthetic.

The Glasgow Committee also tested the effects of numerous other organic liquids.[2] Thus **Dutch liquid** was found to produce convulsions before true anæsthesia appeared; **butyl chloride** caused breathing to cease very soon after anæsthesia had become established; **acetone** set up only slight effects in a frog, even after a long administration; and **benzene** caused struggling and cardiac weakening, although the latter effect was not so marked as with chloroform. As regards the first named of these anæsthetics—Dutch liquid—this had previously been experimentally studied by Snow, Simpson, and Nunneley, and actually used in practice.

The Committee also tested the anæsthetic properties of **isobutyl chloride, methyl chloride,** and **ethyl chloride.** With the first-named drug rabbits and dogs were completely anæsthetised in from three to five minutes, and respiration was unaffected even after half an hour's administration. With human beings, however, isobutyl chloride produced excitement and proved itself to be but an imperfect anæsthetic.[3] With methyl chloride the Committee were unable to obtain any other effect than drowsiness, the rabbits on whom they experimented

[1] *Brit. Med. Journ.*, 4th Jan. 1879, p. 1.
[2] *Ibid.*, 4th Jan. 1879, p. 1. [3] *Ibid.*, 21st June 1879, p. 923.

preserving their reflexes even after a prolonged administration. Ethyl chloride was found to produce rapid general anæsthesia; but in one case respiration ceased, and in another general convulsions supervened. Kemp[1] has also come to somewhat similar conclusions as regards this agent, for he records stertor, difficult respiration, tremors, and convulsive movements of the legs as taking place under its influence.

Tetrachloride of carbon has been experimentally studied by Laffont, Rabuteau, and Morel. Frogs are slowly anæsthetised by it, and recover slowly from its influence. It is stated that in warm-blooded animals a powerful effect is produced, excitement and muscular spasm—both tonic and clonic—appearing, whilst during the period of anæsthesia the heart beats rapidly and the blood-pressure falls.

The physiological properties of **bichloride of methylene** have been investigated by Regnauld,[2] Villejean, and Richet. According to Dastre, the first two of these observers found that whilst anæsthesia came about very rapidly, the muscular excitement which the drug produced was so violent that the agent could not be regarded as an anæsthetic in the ordinary sense of the word. In addition to general muscular spasm of a tetanic character, epileptiform and choreiform movements appeared, and these persisted even after the anæsthetic effects had passed off. Richet has also administered bichloride of methylene to lower animals, and states[3] that the muscular phenomena resemble those of asphyxia, whilst the anæsthesia disappears very rapidly. The properties of the anæsthetic liquid introduced under the name of "bichloride of methylene" or "methylene" by Richardson will be discussed in the clinical section of this work (p. 397).

Acetate of ethyl, or acetic ether, has been used to anæsthetise frogs. It is stated that it is decomposed in the blood into acetate of soda and alcohol, and that anæsthesia is produced by the latter (Dastre); there is, however, little ground for this assertion.

The anæsthetic properties of **carbonic acid** gas have long been known to physiologists; and the interesting experiments

[1] *New York Med. Journ.*, 2nd Dec. 1899, p. 804.
[2] *Soc. de Biol.*, 22nd March 1884.
[3] *Dict. de Physiologie.*

of Mojon, Ozanam,[1] Paul Bert, and Gréhant[2] have added much to our knowledge concerning this body. The last-named observer found that the best results were obtained with mixtures containing as much as 45 per cent of carbonic acid and a proportion of oxygen equal to or in excess of that present in atmospheric air.[3] With such mixtures rabbits were deeply anæsthetised in two minutes, and it was possible to maintain anæsthesia for a prolonged period. Respiration was much reduced in frequency, but its rhythm was unaffected. Blood analyses showed that the oxygen percentage remained constant, but that the CO_2 was greatly increased, oscillating between 80 and 90 per cent. With less than 45 per cent of carbonic acid in the mixture breathed it is stated that anæsthesia did not supervene. Richet[4] points out that carbonic acid is not eliminated as rapidly as many other anæsthetics, because, whilst within the organism, it plays the part of an acid and combines with the alkalies of the blood and tissues.

The effects produced by the **indifferent gases** will be subsequently studied (p. 381).

It has been shown that when introduced into the veins, **chloral** is capable of producing general anæsthesia (Oré), but there are considerable risks in such a procedure.[5]

Finally, a few researches have been conducted with mixtures of anæsthetics one with another, and with mixtures of anæsthetics with liquids not necessarily possessed of anæsthetic properties. Thus the **A.C.E. mixture** (p. 390) has given results very similar to those of chloroform. Kemp found[6] that when the vapour of this mixture was administered to dogs with 95 per cent of air the carotid tracings closely resembled those obtained with chloroform, and that when the air-supply was lessened very pronounced chloroform effects appeared. Leonard Hill's tracings (p. 93) are also of interest in this connection. Upon the kidney Kemp found that the A.C.E. mixture produced the same effects as chloroform, provided that the open method

[1] *Académie des Sciences*, 25th Feb. 1858.
[2] *Soc. de Biologie*, 29th Jan. and 12th March 1887.
[3] See Dastre, *op. cit.* [4] *Dict. de Physiologie.* [5] See Dastre.
[6] *New York Med. Journ.*, 25th Nov. 1899.

were used; but when a semi-closed method of administration was adopted the effects resembled those of ether. The renal secretion was more copious than with pure ether, but less copious than with chloroform; whilst albuminuria was produced in a greater degree than with the last-named anæsthetic.

PART II

PRELIMINARY CONSIDERATIONS BEFORE ANÆSTHETISATION

CHAPTER V

THE GENERAL PRINCIPLES TO BE OBSERVED IN SELECTING ANÆSTHETICS AND METHODS OF ADMINISTRATION

In opening the clinical or practical part of the subject it may be well to clearly define certain terms which will be constantly employed. The term **anæsthetic** will be used to include not only the simple or fundamental substances, such as nitrous oxide, ether, etc., whose properties have been considered in Part I., but also all stable mechanical **mixtures** of these bodies, such, for example, as the A.C.E. mixture. The term **sequence** or **succession** will be used when two or more anæsthetics are administered consecutively. We shall, for example, speak of the nitrous oxide-ether sequence, the A.C.E.-ether-chloroform succession, etc. When an anæsthetic, mixture, or succession is administered according to a particular but broad principle, we shall speak of this or that **system** of administration. To Paul Bert, for example, belongs the credit of introducing the system of administering oxygen with nitrous oxide; to Clover that of administering ether with a limited air-supply. The term **method** will be restricted to actual means by which the anæsthetic, mixture, or succession is administered. For example, Clover's system of employing nitrous oxide and ether in succession may be put into force by the use of different **methods.** Paul Bert's principle or system of obtaining non-asphyxial nitrous oxide anæsthesia may be carried into practice by employing either his method or those of others. And lastly, it will also be convenient to speak occasionally of certain **modifications in methods.**

The anæsthetist of to-day has at his disposal not only a considerable number of anæsthetics, mixtures of anæsthetics, and

successions of anæsthetics, but also a great variety of methods of administration. Putting aside for the present certain exceptional circumstances, to which reference will subsequently be made, it may be said that the practice of employing one anæsthetic for all cases must now be regarded as belonging to a bygone time. To ensure success in inducing and maintaining general anæsthesia we must vary our anæsthetic and our methods of using it, according to the exigencies of the case with which we have to deal.

Of the simple or fundamental anæsthetics referred to in Part I., there are only three which need engage our attention on the present occasion, viz.—

Nitrous Oxide,
Ether, and
Chloroform.

Of the mixtures, those known as

The A.C.E. mixture and
The C.E. mixture

are worthy of notice. And of the successions or sequences of anæsthetics, the following are the most important and useful:—

The Nitrous Oxide-Ether sequence;
The A.C.E. (or C.E.)-Ether sequence;
The Ether-Chloroform sequence;
The Nitrous Oxide-Ether-Chloroform sequence;
The A.C.E. (or C.E.)-Ether-Chloroform sequence; **and**
The A.C.E.-Chloroform sequence.

In attempting to formulate principles for the selection of anæsthetics, we have, in the first place, to decide what means should be adopted for inducing and maintaining anæsthesia in **ordinary or routine practice.** With this section of the subject the present chapter will deal. Next, we have to decide what modifications in this routine practice are advisable when about to anæsthetise patients belonging to this or that type, or suffering from this or that condition. This part of the subject is discussed in Chap. VI. And in the third place, it is

necessary to indicate the special lines of practice which should be pursued in administering anæsthetics for certain operations, procedures, or conditions. This part of the subject is considered in Chap. VII.

In deciding upon the means to be employed for inducing anæsthesia in ordinary or routine practice, it is clear that our first and most important duty is to select that anæsthetic and that method of exhibiting it which is most free from risk to life.

This naturally brings us to the two important questions: (1) Which is the **safest** of the various general anæsthetics? and (2) Bearing in mind the possibility of the safest anæsthetic not being suitable for all cases, which is the **next safest** agent? In considering these questions we shall only take into account nitrous oxide, ether, chloroform, and mixtures containing the last-named anæsthetic.

(1) The first question is not difficult to answer. It is universally admitted that nitrous oxide is the safest general anæsthetic at present known. When given by one who has become familiar with its action, there is, practically speaking, no risk in its administration. With regard to the infinitesimal danger which attends its use in less skilled hands, it is highly probable that this is altogether removed by administering the gas with oxygen, *i.e.* by cutting out the asphyxial factor of the usual mode of administration. If this be so, and the examination of fatal cases would favour such a view, we are justified in giving the preference to the mixture of nitrous oxide and oxygen so far as the actual safety of the patient during artificial anæsthesia is concerned. No fatality from this mixture has been recorded; and from the experience which I have myself had with it, I cannot conceive that any disaster could possibly arise from the direct effects of the two gases, provided, of course, that the oxygen is present in proper proportions. The difference, however, so far as danger to life is concerned, between nitrous oxide on the one hand, and nitrous oxide and oxygen on the other, is so slight that we are warranted in disregarding it; and we may therefore continue to speak of nitrous oxide as the safest anæsthetic known.

(2) With regard to the second question considerable differ-

ence of opinion has hitherto existed. Nitrous oxide bein inconvenient or inapplicable for most surgical operations, it of great importance that every member of the profession shoul know which is the safest of those agents which are suitab for prolonged administration. We are fortunately now in position to unhesitatingly assert that next to nitrous oxid ether is certainly the safest of all anæsthetics.

Statistics as to the relative safety of ether, chloroform, and oth agents are unquestionably open to grave fallacies, and must be accept with caution. So-called "deaths under anæsthetics" are often deat partly or wholly attributable to other causes than to the influence of t anæsthetic itself, and, conversely, fatalities which should be proper ascribed to anæsthesia are often either never reported or regarded as d to "surgical shock," "collapse," etc. Again, statistics generally igno those cases of fatal bronchitis and pneumonia which undoubtedly occasio ally follow the use of anæsthetics, and particularly ether, and whic should in all fairness be included in any statistical inquiry. Moreove the personal element—the experience of the administrator or admini trators in any given series of cases—is often not taken into accoun And lastly, it must be remembered that desperate cases are ofte regarded as unsuitable for chloroform, so that ether is chosen for them with the result that the ether death-rate is thereby unfairly increase Still, with all these objections to statistics, there can be no doubt th they have their value. Whilst they may be regarded as roughly indica ing the relative risks of ether, chloroform, etc., during anæsthesia, the cannot be accepted as representing the true relative death-rates.

The late Sir B. W. Richardson[1] obtained records of 35,162 chlor form administrations with 11 deaths, giving a death-rate of 1 in 319 and of 8431 ether administrations with but 1 death.

It is stated[2] that in the Crimean War there were 20,000 chlorofor administrations with but 2 deaths.

Dr. Julliard[3] of Geneva has collected, from various reliable source records of no less than 839,245 ether and chloroform administration The following table shows the relative frequency with which chlor form and ether were used, and the relative death-rate :—

Anæsthetic.	Total No. of Administrations.	Total No. of Deaths.	Death-rate.
Chloroform . . .	524,507	161	1 in 3258
Ether	314,738	21	1 in 14,987

[1] *Asclepiad*, Jan. 1892.

[2] Dastre, *op. cit.*

[3] *L'Éther est-il préférable au Chloroforme?* Par M. le Professeur Julliard d Genève. (Extrait de la Revue Médicale de la Suisse romande, No. 2, février, 1891.

Dr. Ormsby of Dublin has put on record[1] the following administrations :—

Anæsthetic.	Total No. of Administrations.	Total No. of Deaths.	Death-rate.
Chloroform . .	152,260	53	1 in 2873
Ether . . .	92,815	4	1 in 23,204
Chloroform with ether	11,176	2	1 in 5558
"Bichloride of methylene" . .	10,000	2	1 in 5000

At the 1890 meeting of the German Surgical Society it was resolved to collectively investigate the relative safety of anæsthetics. 24,625 cases were reported[2] during six months. Of these there were 22,656 chloroform administrations, with 6 deaths, two of which, however, occurred from other causes than the anæsthetic. This would give a chloroform death-rate of about 1 in 5500.

Körte[3] has collected records of 133,122 chloroform administrations with 46 deaths, giving a death-rate of 1 in 2894 cases.

At St. Bartholomew's Hospital, during the years 1876-96, there were 58,787 administrations of chloroform, ether, and "gas and ether"; and the following table shows the fatalities and death-rates :—

Anæsthetic.	Total No. of Administrations.	Total No. of Deaths.	Death-rate.
Chloroform . .	30,871	21	1 in 1470
Ether and "Gas and Ether" .	27,916	4	1 in 6979

The ether death-rate is higher than is usual owing to two patients with intestinal obstruction being included, both of whom were collapsed before operation.

[1] *Brit. Med. Journ.*, 14th April 1877, p. 446.

[2] See Gurlt's Summary, *Archiv für klin. Chirurgie*, vol. xlii. pp. 282 and 301.

[3] *Deutsche med. Zeit.*, 12th Feb. 1894.

If we combine Dr. Julliard's statistics with those of Dr. Ormsby w obtain the following results :—

Anæsthetic.	Total No. of Administrations.	Total No. of Deaths.	Death-rate.
Chloroform . .	676,767	214	1 in 3162
Ether . . .	407,553	25	1 in 16,302

In other words, statistics seem to show that **ether is, roughly, mor than five times as safe as chloroform.**

If further evidence be deemed necessary in favour of ethe as a routine anæsthetic for general surgical purposes, we migh quote the views of eminent surgeons and others who are qualified to offer an opinion on the subject. I submit that n surgeon or anæsthetist who has exclusively or almost exclusively employed one anæsthetic should be allowed t influence the judgment of others in this matter; for he would naturally enough be biassed in favour of that agent with which constant practice had made him familiar. But there ar innumerable surgeons and practitioners, many of whom hav specially devoted themselves to administering anæsthetics, whose opinions, seeing that they are based upon the comparative study of the various agents in use, possess the greatest possible weight. We can have no stronger testimony than theirs; and such testimony is almost without exception favourable to ether and unfavourable to chloroform.

The great advantage of ether over all other general anæsthetics at present known is that it produces a remarkably stimulant effect not only upon the circulation, but upon the respiration. The circulation of the etherised patient is not easily or quickly depressed, either by an overdose of the anæsthetic or by other causes. Those accidental conditions, which may seriously lower cardiac action during chloroformisation, have less influence in a patient under ether. The sitting posture is not liable to be attended by evidences either of circulatory or of respiratory depression. The act of vomiting is rarely if ever accompanied by syncope. Moderate deprivation of air is an advantage rather than a danger. Lastly,

patients are not so susceptible to grave reflex circulatory depression as when chloroform is being exhibited.

The respiration under ether is almost invariably so deep and audible that the slightest departure in the direction of failure must at once attract attention. This, in actual practice, is a great point in its favour. The respiration under chloroform, although one of the most reliable of guides as to the depth of anæsthesia, is so often shallow and quiet, even though the patient is doing well, that the anæsthetist is more likely to overlook symptoms of a dangerous character when they first arise. There is another point worth mentioning now that we are comparing the breathing under ether with that under chloroform. Owing to the greater strength of the respiratory movements under the former anæsthetic, there is less objection to placing the patient in certain constrained positions than when chloroform is being administered (see p. 140).

In moderately healthy persons the use of ether is practically free from risk; whereas the majority of those who have unfortunately succumbed under chloroform have been in a robust, or, at all events, a fair state of health at the time.

When dealing with such powerful agents as those we are considering, an allowance must always be made for errors in administration. To hit off, as it were, the exact level of anæsthesia which is appropriate in every case is not an easy matter. The advantage of ether here comes out very prominently; for even when this agent is administered in toxic quantities, in the vast majority of instances the administrator has ample time to resuscitate his patient. The workable area with ether is a large one; that with chloroform is small. We may with ether err either on the side of too light or too deep an anæsthesia, with but little risk to the patient. But with chloroform any departure from that depth of anæsthesia which is proper in each particular case, whether on one side or the other, is liable to be attended by difficulties. When toxic symptoms arise under ether we find the circulation remaining, comparatively speaking, but little affected. This is not so with chloroform. Whatever may be the precise sequence of events in death from an overdose of the latter anæsthetic, the clinical fact remains, and will always remain, that the fatal phenomena

are essentially circulatory. Failure to resuscitate the patien is due to the impossibility of restoring cardiac action.

Ether is certainly rather more difficult to administer tha chloroform, owing to the requisite apparatus being more com plex; but this objection is too trivial to need consideration It is, moreover, difficult or impossible to administer ether i **tropical climates**, or where portability has to be studied, as upo the **field of battle.**

With the above considerations before us, we may certainl regard **nitrous oxide** and **ether** as our **two routine anæs thetics**; the one to be employed for very short operations and the other for those of longer duration. The vast majorit of cases may be successfully anæsthetised by one or other o these two agents. There are, however, certain cases in which owing to the state of the patient, or to the nature of the opera tion, some other anæsthetic is preferable. These cases will b discussed in the two following chapters.

The system by which nitrous oxide is administered, a well as the method employed, must depend upon the view and experience of the anæsthetist. For example, by adminis tering air or oxygen with this anæsthetic the anæsthesia ma be extended far beyond that limit which is attainable wit nitrous oxide alone (see pp. 235 and 244).

The same, too, may be said with regard to ether. Whils the "close" system (p. 272) of administration is undoubtedl the best for general use, the want of a special appliance or th lack of experience in its employment may render the "semi open" system the most appropriate (p. 270). For example, in country districts, in which a practitioner is seldom called upon to give an anæsthetic, the simple administration of ether from a towel folded into the shape of a cone, in the apex of which a sponge is placed for the reception of the ether, may meet the case. Although inferior in many respects to other methods, this one certainly has the merits of safety and simplicity. The nitrous oxide-ether sequence (p. 402) and the A.C.E.-ether sequence (p. 413) are more particularly applicable in the case of experienced administrators.

The A.C.E. mixture occupies a position which, from the point of view of safety, is between ether and chloroform; and,

speaking generally, should be used when nitrous oxide and ether are unobtainable. The cases in which it is specially indicated, in *preference* to these anæsthetics, will be referred to in the two following chapters.

Finally, when neither nitrous oxide, ether, nor the A.C.E. mixture can be obtained, or when, for some particular reason to which reference has been or will be made, neither of these agents is applicable, chloroform must be administered. The best systems and methods of chloroform-giving are discussed in subsequent parts of the work (pp. 313 *et seq.*). The use of chloroform, from the beginning to the end of an administration, is, for reasons to be subsequently considered, open to certain objections which do not apply when this anæsthetic is used after ether. For example, when the ether-chloroform sequence is employed, or its further developments, the nitrous oxide-ether-chloroform or the A.C.E.-ether-chloroform sequence, are used, chloroform anæsthesia may be maintained with a risk to life which is so small that it compares very favourably with, if it does not actually reach, that of ether anæsthesia. These developments, however (which will be fully considered in Chap. XIV.), are of comparatively limited application: they cannot be recommended except for those whose experience in anæsthetics is considerable.

CHAPTER VI

SPECIAL CONSIDERATIONS IN THE SELECTION OF ANÆSTHETIC AND METHODS: (*a*) THE STATE OF THE PATIENT

A CAREFUL consideration of the state of the patient is essentia not only in deciding upon the anæsthetic and the method (its administration, but in forming an opinion as to the proba bilities of certain difficulties or dangers arising during th induction or maintenance of anæsthesia. The typically health patient is by no means necessarily the best subject for a anæsthetic. It is a popular fallacy to imagine that, becaus the heart-sounds are normal and no visceral disease can b detected, the anæsthesia will run a perfectly normal an straightforward course. On the contrary, the best subject for anæsthetics are to be found amongst comparatively feebl persons. Were it merely a question of the supervention (toxic phenomena, the matter would be a simple one, for th strongest and healthiest patients would as a general rule b less liable to give cause for alarm than their more weakl fellows. Such, however, is not the case. Given a particula state of danger, it is of course true that asthenic subjects an those with morbid states of heart or lungs will not be able t hold out against a strain as long as stronger persons. But i we wish to avoid accidents we must study not so much th threatening symptoms themselves as the causes upon whicl they may depend. We shall then find ourselves face to fac with an important fact, and one which has hitherto not beer fully realised, that certain subjects, and not necessarily th most feeble and exhausted, are more prone than others to th development of intercurrent asphyxial symptoms, and that it i

this intercurrent state which is the *fons et origo mali.* From the point of view of the anæsthetist, then, patients may be arranged in classes or types according as they do or do not possess certain of the conditions enumerated and considered in this chapter.

Patients of a particular type display particular symptoms under particular anæsthetics; whilst those of other types display other symptoms, although treated on precisely the same lines. There are, in fact, "good" and "bad" subjects for anæsthetics, and in order to foretell what course the anæsthesia will run a large number of points must be taken into consideration.

A. SEX AND AGE

Sex.—Sex has a distinct, though probably only an indirect, influence upon the effects produced by general anæsthetics. Taken as a class, women certainly pass very easily into deep anæsthesia—a fact which may be explained by their physique being, as a rule, inferior to that of men (*vide infra* D).

At the extremes of life, *i.e.* when differences in muscular development are very slight, the influence of sex is less perceptible. Moreover, men with feebly-developed muscular systems take anæsthetics very much in the same manner as women, and women of masculine type display similar symptoms to those of men. Emotional disturbances are commoner in women than in men.[1]

Age.—Similarly, the age of the patient has of itself no intrinsic influence in modifying the effects produced by anæsthetics. It is rather the presence, at different periods of life, of different physical and other conditions which must be considered. The invariable use of chloroform, for example, for patients between certain ages, and of ether for patients at other periods of life, cannot be regarded as rational.

General anæsthetics may be given to patients of all

[1] See p. 339. Of the 210 chloroform fatalities referred to only 59 or 60 occurred in females.

ages. Infants but a few hours old may be safely anæsthetised; and anæsthetics have been successfully administered to centenarians.

The upper air-passages of **infants and very young children** are so sensitive that ether often causes some irritation and respiratory difficulty. This has led many to prefer chloroform, which is certainly inhaled with comparative ease by children. It is a mistake, however, to suppose that children are not so susceptible as adults to the toxic effects of this agent, and that with them fatalities are practically unknown. It is true that children inhale chloroform freely, and that they are not as prone as adults to certain forms of respiratory embarrassment. It is certain also that children may be rescued from conditions of respiratory and circulatory depression which in adults would be attended by more immediate risk to life. But children are occasionally placed in considerable peril by chloroform, and more fatalities under this anæsthetic have been recorded than might be imagined.[1] Although chloroform is apparently better borne than ether by children, it nevertheless possesses certain special disadvantages in these subjects. It not unfrequently induces an extremely tranquil and sleep-like respiration which deprives the administrator of the most important means of knowing how deeply his little patient is anæsthetised. This reason is alone sufficient to warrant us in the use of ether in some form or another for very young subjects. When ether is properly and carefully given to infants they take it far better than is generally believed. Some form of semi-open inhaler[2] should be used, and plenty of air given. (See Illustrative Case, No. 10, p. 312.) It is necessary to be careful in administering chloroform or its mixtures during the crying and

[1] Comte, who has collected records of 232 chloroform fatalities, found that of this number, 21 occurred in children. Weir states that no death is recorded under ether given to patients under 12 years of age. *New York Med. Jour.*, 1st March 1890.

[2] Mr. Woodhouse Braine administers ether to children, and with the best results. He employs small cones made of lint, and drops the ether upon the lint. I have often followed this practice, and believe that, when care is taken, there is very little if any risk of bronchitis supervening. I rather prefer cones of felt to cones of lint. In Oct. 1899 I anæsthetised, at the London Hospital, for Mr. Eve, an infant 6 days old, employing ether in this way. The operation was for spina bifida and lasted about 35 minutes. I am convinced that the infant would not have done nearly so well had chloroform been used.

struggling stage: it is a good plan to temporarily remove the inhaler just as this stage is subsiding, otherwise an unnecessary quantity of the anæsthetic may be introduced and the circulation or respiration unexpectedly depressed. The C.E. or A.C.E. mixture answers well in infants; and when the operation is likely to be of some duration is more appropriate than ether itself. The A.C.E.-ether succession, as recommended by Mr. Geo. Rowell, is also useful in these subjects.[1] For children of two or three years of age the best plan is to commence with a small quantity of the mixture till the crying, which is almost inevitable, has nearly subsided, and then to proceed with ether from a Clover's Portable Regulating Inhaler (Fig. 28, p. 273), the indicator of which should be placed about half-way between "0" and "1." If a little care be taken not to give too strong a vapour of ether, and not to keep the inhaler applied for more than a few moments at a time, it will be found that respiration, though moist, quickened, and noisy, will not become nearly so embarrassed as when these simple precautions are not observed. Mucus is often produced in considerable quantities; but this need cause no anxiety to the administrator. Ether inhalers in which it is difficult or impossible to regulate the strength of vapour to the requirements of the case are not so suitable for anæsthetising very young children. Nitrous oxide is not an appropriate anæsthetic for children under three or four years of age, although, if given with suitable percentages of oxygen, it answers far better than when otherwise administered. The fragile thoracic parietes seem to be unable, in many cases, to efficiently meet the demands made upon them by the necessary valves and other parts of the inhaler. Pure nitrous oxide may rapidly bring about, in a small child, a very undesirable state of asphyxia. As a preliminary to ether, however, pure nitrous oxide is very valuable in children over three or four years of age, for the initial anæsthetic need only be given in small quantity. After a few breaths of nitrous oxide an Ormsby's inhaler charged with ether may be loosely applied, and deep anæsthesia will be rapidly induced. This plan has the great advantage that all crying and struggling are prevented—often a point of some importance—for if the administrator can coax

[1] "The Anæsthetisation of Children," *Lancet*, 15th May 1897.

his little patient to take but three or four breaths of nitrou oxide, unconsciousness will immediately ensue.

Patients advanced in years generally take anæsthetics bette than middle-aged or more vigorous subjects. They are les prone to muscular spasm; they usually require smaller quan tities of the drug employed to produce desired effects; and by reason of the frequency with which their teeth are defective an oral air-way is more readily available for respiratory pur poses. Ether may be given to old people if the respirator functions have not become seriously impaired by senile o other changes. It is best, as a rule, to precede ether by small quantity of the A.C.E. mixture (see p. 413); and air limitation should not be practised too freely. Nitrous oxid followed by ether is not so satisfactory as the succession o anæsthetics here recommended. It must be remembered tha ether produces a deeper and more rapid respiration tha chloroform or its mixtures, and it sometimes happens, whe etherising old people, that the respiratory apparatus finds som difficulty in meeting the demands made upon it. When th respiration, by reason of degenerative changes within the lung and chest walls, has become more abdominal than thoracic when much emphysema or chronic bronchitis is present; o when there is considerable obesity, with shortness of breat and indications of rather defective blood oxygenation, ethe may cause difficulties in breathing. In these cases th A.C.E. or C.E. mixture is a most valuable anæsthetic, an is very satisfactorily borne by aged subjects who do not tak ether comfortably. A few cases, however, will be met with i which chloroform should be given in order to secure tranqui anæsthesia. Nitrous oxide may be administered to very elderl people, but care must be exercised. The gas should not b pushed quite so far as in younger subjects, otherwise, when th inhaler is removed, respiration may not recover itself a quickly as is desirable.[1] The use of oxygen with nitrous oxid is specially indicated in senile subjects (see p. 251).

[1] Mr. Braine and Mr. Bailey have given nitrous oxide to patients over 9 years of age.

B. TEMPERAMENT

Patients of a **placid and equable** temperament are, as a rule, somewhat easier to anæsthetise than **excitable, highly-strung, and neurotic** persons. Nitrous oxide is an excellent anæsthetic for patients of the latter class, for by its means excitement—at all events during the administration—may be abolished. When longer anæsthesia is required, nitrous oxide may be followed by ether with the best results. Reflex actions are, for the most part, more marked and more difficult to subdue in neurotic and hysterical persons than in those of a non-excitable temperament. As pointed out by Snow, hysterical subjects may display an absence of corneal reflex even though anæsthesia is not fully established. Muscular rigidity is sometimes a troublesome phenomenon in neurotic subjects; and, when very sensitive parts are being operated upon or manipulated, there is often a tendency, even during deep anæsthesia, for slight movement or other reflex effect to manifest itself. Screaming, sobbing, and other emotional disturbances, during recovery from the effects of the anæsthetic, are much more common in hysterical and nervous persons than in those of an opposite temperament. In anæsthetising sensitive and fastidious subjects considerable judgment and tact may be needed; in some cases one method will be appreciated, whilst in others another must be adopted. The gradual administration of A.C.E. or alternate inspirations of nitrous oxide and air may be advantageously resorted to in such cases.

C. HABITS OF LIFE

Patients whose nervous systems have become undermined by alcoholic indulgence, the morphia habit, the excessive use of tobacco, chloral, or other narcotics generally display abnormal symptoms during or after anæsthetisation.

The behaviour of **alcoholic subjects** under anæsthetics is generally perfectly characteristic. Considerable quantities of the agent employed may be required to produce the requisite degree of quietude. I have had, for example, to administer 5½

ounces of chloroform, in $1\frac{1}{4}$ hour, to an alcoholic man of fifty-six; and correspondingly large doses of nitrous oxide, ether, or other agents may be needed. It is occasionally difficult, if not impossible, to secure total muscular relaxation in patients of this class, and reflex movements during operations upon sensitive parts may obstinately persist, even though dangerously large quantities of the anæsthetic be administered. In confirmed alcoholics the stage of muscular excitement is usually prolonged, and, at all events with chloroform, there is need for caution during the rigidity and irregular respiration (see p. 330). In certain exceptional cases nitrous oxide seems incapable of producing anything more than an analgesic state. If the gas be given without oxygen, clonic and tonic spasm come about abnormally early and cut short the administration, whilst if oxygen be mixed with the gas, the anæsthetic element may be insufficient to induce true narcosis. Recovery from anæsthesia is usually abrupt, and nausea and vomiting are rare. It is quite a common event for an alcoholic patient to regain incoherent speech and co-ordinated movement in two or three minutes after the withdrawal of the anæsthetic, even though corneal insensibility and stertor have been present up to the very end of the administration.

The habitual use of **morphia** may render patients more susceptible than they otherwise would be to the influence of anæsthetics, particularly if, as may be the case, an injection of this drug has been given shortly beforehand (see p. 421).

The excessive use of **tobacco** may lead to an irritable condition of the pharynx and larynx, and to troublesome coughing during the administration. Hesitating breathing, widely dilated pupils, and tonic or even clonic spasm over most of the body may be met with in great smokers.

Some of the most difficult subjects I have had to anæsthetise have been heavy smokers. One man, a patient at the London Hospital, admitted smoking 1 oz. of "plug" tobacco daily. His heart-sounds were very distant and his pulse slow, but no evidence of intrathoracic disease was detected. Ether was given, but it was taken very badly, so chloroform was substituted with little or no improvement. The breathing was much embarrassed, the jaws so rigid that they could hardly be separated by the strongest gag, there was profuse secretion of (?) laryngeal and tracheal mucus, with a moist expiratory râle, and the abdomen was so

rigid that the operation could hardly be performed. It was, in fact, with the greatest difficulty that anæsthesia was maintained.

I have notes of several other cases in which somewhat similar symptoms have arisen. The chief difficulty is apparently due to exaggerated spasm of muscles about the floor of the mouth, jaws, and neck. It is quite conceivable that in excessive smokers these muscles may be abnormally developed, and, in consequence of this, inconvenient spasm may arise.

Patients who have taken **anæsthetics on several previous occasions** seem to display less susceptibility to their influence at each administration; and those who have been anæsthetised a large number of times are liable to prove difficult subjects on this account. A tendency to vomiting at the first breath of the anæsthetic, swallowing movements, and obstructed breathing are liable to arise in such cases.

High living, more especially if associated with want of exercise, leads to obesity, plethora, and other conditions, which, as will be presently shown, are capable of modifying the effects of anæsthetics (see p. 122).

D. GENERAL PHYSIQUE

The **healthy, vigorous, and stalwart** subject does not pass so easily into anæsthesia as the weaker and more **fragile** patient. This would seem to be principally due to the stage of excitement being more marked, and to muscular spasm, interfering with respiration, being more pronounced than in feeble subjects. The amount of anæsthetic needed to produce sleep will be found to vary very considerably with the general physique of the patient, the total quantity of blood within the vascular system constituting an important factor. For example, a man of six feet in robust health may require from eight to ten gallons, or possibly more, of nitrous oxide, before he is completely anæsthetised; whereas an ill-nourished young woman of short stature may exhibit all the signs of complete anæsthesia from this gas after inhaling from two to three gallons. Emaciated children need remarkably small doses of an anæsthetic.

Should the patient possess a thick beard or moustache some delay may arise, when employing nitrous oxide or ether, by reason of the difficulty of preventing air from gaining admission under the cushion of the face-piece.

Patients who are the subjects of extreme **obesity** usually exhibit phenomena differing somewhat from those met with in thin and spare individuals. As a general rule they are intolerant of any anæsthetic which, by reason of the method of administration employed, limits the supply of air to any considerable extent. The C.E. mixture and chloroform are therefore usually better borne by such subjects than nitrous oxide or ether. There are, however, certain exceptional cases amongst obese and alcoholic men in which chloroform, when administered to the full surgical degree, produces obstructed respiration, and in these a change to ether must be effected.

Patients with a **florid colour**, as well as those who are distinctly **plethoric**, require more anæsthetic than anæmic and sallow persons. For reasons which I have elsewhere[1] given in detail, respiration is more likely to become hampered in full-blooded patients than in those of an opposite type. It is sufficient to say, in the present place, that the parts constituting the boundaries of the upper air-passages may, in vascular subjects, become so engorged as to lessen the capacity of those passages. This vascular turgescence and consequent swelling is most pronounced under nitrous oxide or ether, but may also be observed under other anæsthetics, and appears to be often partly dependent upon the degree to which air-limitation is allowed to occur during the administration. The tongue of a plethoric, short-necked patient under nitrous oxide may, for example, become noticeably increased in size. The so-called "falling back of the tongue" is often partly or wholly the outcome of an increased size of that organ. Mucus and saliva are usually freely secreted during the administration of ether to young patients, more especially young women of good colour. When the face of the patient is very florid it will rapidly become dusky or cyanosed, should the air-supply be purposely

[1] See "Clinical Observations upon Respiration during Anæsthesia; with Special Reference to the Causes of Embarrassed and Obstructed Breathing" (*Trans. Roy. Med. Chi. Soc.* vol. lxxiv., 1891, p. 107).

or accidentally restricted. Thus, under nitrous oxide or ether, red-faced patients assume an appearance which to the onlooker might cause alarm; moderate duskiness of the features is not of itself indicative of any untoward condition in such cases. As a general rule, florid vascular subjects should be kept deeply anæsthetised; for if only moderate anæsthesia be secured, inconvenient reflex actions will be found liable to result.

Anæmic patients take anæsthetics very well, small quantities being required to secure tranquil anæsthesia. When, however, the anæmia has been induced by loss of blood, as, for example, during the progress of some uterine affection, it may happen that no unusual diminution in the quantity of anæsthetic will be distinguishable. Air-limitation should be practised as little as possible with these subjects, for they are intolerant of any asphyxial state. Nitrous oxide mixed with oxygen is hence a better anæsthetic than the former gas alone. In cachectic and very feeble persons undergoing rather formidable operations it is usually best to secure a fairly deep anæsthesia for the *commencement* of the operation, and then to allow the patient to pass into a condition of light anæsthesia for the *remainder* of the time (see Illust. Case, No. 43, p. 483).

E. THE RESPIRATORY SYSTEM

The manner in which respiration takes place prior to the use of an anæsthetic will influence the phenomena of the administration. It must be remembered that, when consciousness has been destroyed, any pre-existing tendency to embarrassed breathing is likely to become increased. When any such tendency is present it is, therefore, well to ascertain its nature and degree.

The State of the Upper Air-Passages.—Certain symptoms during the use of anæsthetics will be found to be dependent upon the manner in which the **teeth** of the lower jaw engage those of the upper. Patients with powerful jaws and irregular and interdigitating teeth, as well as those with perfect teeth which meet accurately, will be liable to exhibit a greater tendency to hampered breathing than patients whose

teeth are more defective. Moreover, should the upper and lower teeth engage one another in such a manner as to render it difficult to move the lower jaw upon the upper, greater embarrassment in breathing will be likely to arise than under other circumstances (see p. 445). Difficulties in breathing are also not uncommon in anæsthetising patients with ill-developed and receding lower jaws. Should the patient be wholly **edentulous** it may be necessary to keep the gums and lips apart, in order to maintain respiration. **Fixity or lessened mobility of the lower jaw,** from disease of its articulations (see Illust. Case, No. 37, p. 450), from local inflammatory conditions, or from the presence in the submaxillary or cervical regions of glandular or other tumours (see Illust. Case, No. 34, p. 448), is particularly liable to give rise to serious difficulties in breathing.[1] If the nasal air-way be free, breathing will usually take place either partly or wholly through it. If it be more or less obstructed, even by ordinary catarrhal inflammation, the anæsthetist may be obliged to keep open an oral air-way by the use of some form of mouth-prop (Fig. 10, p. 199).

In patients with pre-existing complete nasal obstruction special care must be exercised, and unless the precaution be taken of inserting a mouth-prop, nitrous oxide and "close" methods generally should be avoided. Temporary hindrances to breathing from the causes here indicated are most liable to arise in vigorous young subjects.

Morbid growths of the tongue, soft palate, tonsils, pharynx, epiglottis, and adjacent parts may, from vascular turgescence or alteration in position, interfere with free respiration during anæsthesia. Any deprivation of oxygen is especially liable to lead to this increase in size. Patients with enlarged tonsils will be found, for example, to take nitrous oxide with oxygen (see p. 251) far better than nitrous oxide administered in the ordinary manner, *i.e.* without any oxygen. With the former method respiration at most becomes snoring; whereas, when nitrous oxide free from oxygen is fully administered to a patient with very large tonsils, embarrassed and obstructed

[1] See an interesting case (*Lancet*, 8th April 1899, p. 959), in which nitrous oxide caused fatal asphyxia.

respiration (usually only temporary) will result.[1] But even with non-asphyxial methods, difficulties from enlarged tonsils are very likely to occur. Mr. Bellamy Gardner has found the lateral or semi-prone posture advantageous in cases of extreme enlargement. Glandular, lipomatous, and other tumours of the neck, including thyroid growths, may, during vascular engorgement, seriously lessen the capacity of the air-way, and thus favour obstructed breathing.[2] Should the patient whose air-way has become narrowed suffer from even occasional or slight difficulty in breathing, the advisability of preliminary tracheotomy should be discussed.

When **dyspnœa from laryngeal disease, narrowing of the trachea, or similar conditions** is present, great care must be exercised.[3] Chloroform is the only admissible anæsthetic in such cases, and the depth of anæsthesia induced should bear an inverse ratio to the degree of obstruction. Patients with slight narrowing of the air-tract generally tolerate the anæsthetic state remarkably well; but when the dyspnœa is considerable, the patient somewhat cyanosed and unable to lie down, and sleep is hardly possible, the risks of giving a general anæsthetic are great.[4] The extraordinary muscles of respiration upon which the patient has become dependent are thrown out of action during unconsciousness, the result being that respiration is left to the care of muscles which are incapable of overcoming the difficulties present. In this way respiratory arrest may readily arise even though the corneal reflex be intact. In anæsthetising patients with laryngeal affections, a careful consideration of the precise nature of the disease is essential. In cases of abductor paralysis, for example, it may be necessary to keep the chin forcibly pulled away from the sternum throughout the administration, otherwise dangerous approximation of the lax cords may result.

[1] Mr. Bailey (*Brit. Med. Journ.*, 29th March 1884, p. 645) refers to a case of carcinoma of the tonsils in which respiration ceased (probably in the manner suggested in the text). Tracheotomy became necessary.

[2] See a case, *Lancet*, 1st September 1888, p. 442, and *Brit. Med. Journ.*, 15th September 1888, p. 625. Also *Brit. Med. Journ.*, 29th October 1892, p. 964.

[3] Mr. Bellamy Gardner has in an interesting paper (*Lancet*, 11th June 1898) discussed the use of anæsthetics in patients with laryngeal paralyses and morbid growths.

[4] Mr. Jacobson (*The Operations of Surgery*, 1st ed. p. 382) holds this view.

The use of anæsthetics during operations for papilloma of the larynx will be discussed in the following chapter.

Bronchial, Pulmonary, and Pleural Diseases.—Should the affection be slight, and of a chronic character, and the operation short, ether is not necessarily contra-indicated, although as a general rule the A.C.E. mixture is preferable. Should there be a history of hæmoptysis or symptoms of acute or extensive bronchial or pulmonary disease, or should the contemplated operation be likely to be protracted, ether is as a rule best avoided. There are, however, certain grave cases in which this anæsthetic, although apparently contra-indicated, will give the patient the best chance. The respiratory difficulties which sometimes attend the use of ether in patients suffering from pleural or pulmonary affections are frequently more apparent than real. This anæsthetic, indeed, by maintaining a rather exaggerated form of breathing and a somewhat excited circulation, is particularly suitable when there is any special risk of cardiac failure (see Illust. Case, No. 8, p. 311). When ether is badly borne, the A.C.E. mixture or chloroform may be substituted. So far as the use of anæsthetics is concerned, old-standing lung or pleural affections are of less importance than those more recently acquired. In the former the respiratory mechanism has, by constant use, become adapted to circumstances; whilst in the latter such adaptation is in process of establishment. Patients with **chronic bronchitis, marked emphysema, chronic phthisis, old pleural disease,** and similar conditions hence take anæsthetics well when care is exercised. It is not uncommon for ether to cause, in asthmatic subjects and in those who are suffering from the affections now under consideration, a peculiar form of respiration characterised by prolonged expiratory efforts and by a variable degree of cyanosis. When such symptoms arise during etherisation they may be very quickly relieved by changing to the A.C.E. mixture or chloroform. Nitrous oxide may be safely used in persons with chronic lung affections, but it should not be pushed quite so far as in healthier subjects. When mixed with oxygen the anæsthesia is of a more satisfactory nature than when the gas alone is given. Should the bronchial, pulmonary, or pleural affection under

which the patient is labouring be of recent origin and of sufficient intensity to cause distress in breathing, much caution must be exercised and a deep anæsthesia avoided. It is hardly necessary to point out that the greater the embarrassment to respiration the lighter should be the anæsthesia, and the more careful should the administrator be to allow of a copious supply of air and to prevent all conditions likely to impede breathing during the use of the anæsthetic. It is a fortunate circumstance that patients with respiratory affections are, as a rule, singularly free from those inconvenient reflex manifestations which generally attend a light form of anæsthesia. The most hazardous cases are those in which respiratory embarrassment from **recent pleurisy or pleuro-pneumonia** coexists with quick and hampered cardiac action. When the patient is slightly dusky, his temperature elevated, his breathing rapid, and his pulse accelerated and sharp under the finger, the use of an anæsthetic is attended by considerable risk. This risk is greater in patients with previously fatty and dilated hearts than in others. Numerous deaths have, in fact, occurred in such subjects from syncope during or immediately after transient struggling.[1] It is in such cases as these that I find it best to employ the A.C.E.-ether sequence, applying a semi-open ether inhaler *before* the rigid stage and maintaining only a light anæsthesia.

In certain desperate cases in which respiratory embarrassment, with more or less cyanosis, is associated with cardiac disease or with marked depression of the circulation arising from other causes, it may be advisable to administer oxygen in conjunction with the anæsthetic, care being taken to introduce this gas to the lungs in such a way as to throw no additional work upon the muscular mechanism of breathing.

Wholly Thoracic or wholly Abdominal Respiration.—There are various conditions which may give rise to wholly thoracic or wholly abdominal respiration. The former is most frequently met with as the result of peritonitis, or of extreme abdominal distension from intestinal obstruction, ascites,

[1] A typical example will be found in the *Brit. Med. Journ.* i., 1881, p. 385. Ethidene dichloride was being used; the fatal syncope took place when the patient was turned on to his sound side. At the post-mortem the right heart was full and the left empty.

ovarian disease, etc. The latter is most commonly due to advanced emphysema or other affections of the lungs or pleuræ. Should the breathing be wholly thoracic[1] or abdominal, the administrator will, of course, meet with more exaggerated respiratory movement than usual. If a patient should, from some acute condition, be obliged to use his thorax or abdomen only, and if the new form of respiration should be somewhat difficult for him to acquire by reason of pre-existing conditions, such as emphysema or obesity, anæsthetics must be used with caution. When the **abdomen** is **greatly distended** from ascitic fluid, a light anæsthesia only is necessary during its removal (see Illust. Case, No. 17, p. 394), and the administrator will find that both respiration and circulation will markedly improve as the fluid is evacuated and the lungs become able to expand more freely.

Morbid States of the Central Nervous Mechanism.— For remarks on this subject see pp. 133 and 178.

F. THE CIRCULATORY SYSTEM

The circulation of the patient may be of the most efficient type; or it may be so feeble as to render it questionable whether any operation should be performed. The pulse may be so rapid that it can hardly be counted; or, on the other hand, it may be abnormally slow. When mental emotion is the cause of the quickening, a considerable slowing will invariably occur during anæsthesia; but when the rapid pulse is due to shock, exhaustion, etc., an increase in rate will usually be found to occur (see Illust. Case, No. 43, p. 483). I once gave an anæsthetic to a patient, an elderly gentleman, whose pulse was usually 28 to 30 per minute.[2] A very slow pulse is often met with in patients suffering from cerebral disease. Patients whose heart's action is good and whose pulse is full and strong will be better able to withstand any unwonted cardiac strain (as, for example, that incidental to

[1] In a case reported by me in the *Lancet*, 19th March 1896, p. 772, the diaphragmatic paralysis which was present was probably due to peripheral neuritis; an unusual degree of cyanosis was observed during etherisation, and fatal pulmonary œdema followed.

[2] This case is referred to on p. 296.

any embarrassment of respiration) than patients of less vigorous circulation (see Illust. Case, No. 37, p. 450).

Valvular and other Cardiac Affections.—Patients with these affections may be anæsthetised with safety if care be taken to select the anæsthetic most appropriate to the case, and to administer it in such a manner that no undue strain is thrown upon the heart. Where the cardiac affection is but slight, and, by reason of compensatory changes, the general circulation is good, little or no alteration need be made in the anæsthetist's usual practice.

There are one or two points, however, which should be borne in mind in dealing with **advanced cases.** Unless orthopnœa exist, the recumbent or semi-recumbent posture should be enforced, no marked or prolonged deprivation of oxygen permitted; and any interference with respiratory rhythm prevented. The anæsthesia of nitrous oxide followed by ether is not to be recommended in these cases. A well-marked instance of the ill effect of employing a "close" and asphyxiating method of administration in a patient with mitral obstruction and aortic regurgitation occurred at the London Hospital in 1897; cardiac rapidity and irregularity, with dusky pallor of the face and failing pulse, were observed after a short inhalation of ether by means of Clover's inhaler. Dr. Guthrie records the case of a fat baby, five months old, with congenital pulmonary stenosis, in which chloroform caused early cessation of breathing with cyanosis, and finally pallor. All methods should be gradually conducted, and the slightest respiratory embarrassment assiduously avoided. Speaking generally, the A.C.E. or C.E. mixture is an excellent anæsthetic for patients with advanced morbus cordis (see Illust. Cases, Nos. 19, 20, and 21, p. 395). It may be administered in all forms of valvular disease, and is remarkably well borne. Ether (preceded by a small quantity of the A.C.E. mixture to prevent its disagreeable odour) may be used in cases in which there is no evidence of **great pulmonary or systemic engorgement.** It would also appear to be desirable to employ ether, or, at all events, to attempt its exhibition, in those cases in which **orthopnœa** is present. Such patients, fortunately, rarely require anæsthetics;

but, owing to the position which they are bound to assume, chloroform and its mixtures should be avoided if possible (see Illust. Case, No. 9, p. 312). By the gradual administration of the A.C.E. mixture to a patient with an intermittent or irregular pulse, the heart's action generally becomes steadier, and remains so for a considerable time. The anæsthetist must not, however, shut his eyes to the fact that after the withdrawal of the anæsthetic, or during a serious operation, this improvement may, and often does, become replaced by irregularity and feebleness in excess of the original condition.

The remarks here made with regard to valvular cardiac affections apply with equal force to cases in which **fatty or other degenerative changes** are present in the myocardium. Provided that the respiration be kept free from embarrassment, the "fatty heart" is not injuriously affected by anæsthetics. Any asphyxial strain upon it, however, may quickly impair its action and lead to syncope, the usual course of events in chloroform fatalities which arise during the struggling stage. Moreover, surgical shock is more likely to assume grave proportions in cases of advanced cardiac degeneration than in others.

Atheroma.—In extremely atheromatous subjects there is a slight risk[1] of cerebral hæmorrhage during anæsthesia. This risk may, however, be minimised by selecting the A.C.E. mixture or chloroform in preference to ether; and by avoiding, as far as possible, excitement, holding of breath, coughing, and struggling during the administration. In order to do this the anæsthetist must proceed very gradually with the inhalation, and by a little management he will usually succeed in getting a patient to pass into a state of quiet anæsthesia with little or no trouble. In patients who have previously suffered from cerebral hæmorrhage ether is strongly contra-indicated[2] (see p. 310).

Should arterial degeneration have led to the formation of

[1] See a case which occurred in the practice of Dr. Fuller of Montreal, reported in *Canadian Med. and Surg. Journ.*, March 1888, p. 309, and referred to in Dr. Turnbull's 3rd edition of *Artificial Anæsthesia*, p. 252.

[2] Some years ago a case occurred at the London Hospital, in which a patient, a man of sixty-two, died from cerebral hæmorrhage, which apparently took place whilst he was under the influence of ether. The operation, which was a short one, was for the removal of a growth of the breast. Clover's inhaler

an **aneurysm**, the same caution as to the avoidance of struggling, straining, coughing, etc., must be exercised. It is true that ether has very frequently been given to patients with large aneurysms without rupture having occurred, either during the induction of anæsthesia or during complete narcosis; but when there is any evidence of rapid increase in size, and more particularly when the aneurysm is intrathoracic, the A.C.E. mixture or chloroform should be used in preference to ether.

Venous Thrombosis.—Patients with venous thrombosis must be very carefully treated. They should be moved as little as possible, and special precautions should be taken to avoid struggling and excitement. An interesting and possibly a unique case, in which fatal syncope arose in consequence of a clot from the common iliac vein becoming dislodged and entangled in the tricuspid orifice, is given on p. 475.

Exhaustion. Collapse.—One is often called upon, more particularly in hospital practice, to anæsthetise patients whose circulation has become much enfeebled, either from some long-standing disease or some recently acquired but prostrating malady. As illustrations may be mentioned—cases of hip disease and hectic in children, cases of stricture of the pylorus necessitating gastrostomy, cases of strangulated hernia, and cases of collapse from railway or other injuries. Such patients are very susceptible to anæsthetics, small quantities only being necessary to induce and maintain anæsthesia.

As a general rule, the pulse of the exhausted patient improves in volume when anæsthesia is established; but, directly the anæsthetic is withdrawn, some depression of the circulation may follow. Moreover, this initial improvement does not, as a rule, last long; and any loss of blood, prolonged exposure, or severe surgical procedure will soon give rise to signs of circulatory depression. Should the pulse be quick beforehand it will usually become more rapid during the administration. The administrator must do all in his power to sustain the strength of these patients. If the heart's action be

was used, and there was but little struggling. The patient never became thoroughly conscious after the operation; and hemiplegia was found to be present, and death occurred in a few days.

very feeble, no method of administration should be employed by which the supply of air is greatly restricted, and all mechanical or other hindrances to free respiration must be avoided. Ether is, as a rule, best administered by the semi-open method and in small quantities at a time. If a close inhaler be used, care must be taken to remove it frequently for the admission of air. The administration of nitrous oxide is best avoided in these cases. Exhausted and collapsed subjects are liable to display a peculiar state of the eyes during anæsthesia, and more particularly during deep anæsthesia, the lids failing to close and the globes turning upwards so that the sclerotics only are visible. Profuse sweating is also common in these subjects, and is another indication of exhaustion. The administrator must be on his guard with reference to the rosy cheeks of **hectic subjects** and of those artificially stimulated by alcohol. This florid colour may coexist with a circulation totally unable to withstand any very prolonged surgical interference.

Patients suffering from **intestinal obstruction** are, perhaps, appropriately considered under this heading, seeing that, in extreme cases, syncope of the worst type is not uncommon during anæsthesia. The abdomen is usually distended, and the diaphragm unable to act efficiently; the stomach frequently contains fluid or semi-fluid material; the patient will be found to be, in many instances, partly under the influence of an opiate; and the circulation, though often artificially stimulated by alcohol, may be in reality utterly unable to withstand any strain. When the abdomen is distended and inactive, the pulse quick and feeble, the extremities clammy and dusky, the features pinched and the lids half open, general anæsthesia is extremely hazardous. In less advanced cases an anæsthetic may be given; but caution is very necessary. As the question concerning the use of an anæsthetic in intestinal obstruction, peritonitis, etc., is one of great importance, I would refer the reader to p. 174, and to Illust. Cases, No. 26 (p. 424) and No. 18 (p. 395).

G. THE NERVOUS SYSTEM

Should the patient be drowsy or half-conscious at the time of operation, very small quantities of the anæsthetic will be needed. When well-established coma is present, the services of an anæsthetist will not, of course, be required. The subjects of depressed fracture of the skull, intracranial hæmorrhage, cerebral abscess, or cerebral tumour may, at the time of operation, be so lethargic that a few inhalations of the anæsthetic will readily produce the quietude desired. It must be remembered that patients with cerebral or cerebellar tumours may, apart from the use of anæsthetics, display symptoms of primary respiratory failure from increased intracranial tension; and when any tendency in this direction exists, the induction of even light anæsthesia may completely suspend breathing.[1] The employment of morphine prior to cerebral operations will be specially discussed hereafter (see p. 178).

Patients whose perceptive faculties have become blunted by the absorption of poisonous products during the course of intestinal, vesical, renal, or similar affections often pass into anæsthesia with a marked absence of excitement and rigidity; and display a florid colour and good pulse throughout the administration, provided that the corneal reflex be not completely abolished. Very deep anæsthesia is unnecessary in such cases. I have often been struck by the fact that patients of this kind behave in much the same way as if a preliminary injection of morphine had been given.

Patients who are the subjects of chronic nervous affections may exhibit peculiar respiratory phenomena during anæsthesia. Thus, I have notes of two cases—one patient had **disseminated sclerosis**, and the other advanced **tabes dorsalis**—in which, during the use of an anæsthetic (ether), breathing was jerky, catchy, halting, and split up, as it were, by long pauses. In the ataxic patient some degree of laryngeal obstruction, with prolonged expirations, was noted, and gave me some trouble.

[1] I have related a case of this kind (*Practitioner*, 1887, vol. xxxix. p. 93), and Dr. E. F. Fison of Salisbury (*Lancet*, 4th Aug. 1900, p. 329) records another. In both artificial respiration was maintained for four hours.

The subjects of **epilepsy** may be safely anæsthetised. In some cases a more or less distinct attack occurs during the exhibition of the anæsthetic. I have, on one or two occasions, noticed a greater tendency than usual to tonic and clonic spasm during the administration of nitrous oxide to these subjects.[1] In only one case have I known a distinct and characteristic epileptic seizure to arise, and in this the attack began after a few breaths of the gas, *i.e.* before the occurrence of the usual asphyxial phenomena.

The administration of anæsthetics to patients with a previous history of **insanity** is liable to be followed by a fresh attack. According to Dr. Savage,[2] patients subject to recurrent seizures of mental disorder are particularly liable to be thus affected. There is, apparently, no special objection to anæsthetising patients already insane, except, of course, in the case of maniacal subjects. I have met with one or two cases of exaggerated excitement in patients with a family history of insanity.

H. RENAL DISEASE

Opinions are still divided as to the choice of anæsthetics in patients suffering from renal disease. The fact that very contradictory results have been arrived at by observers who have recently investigated the relative influences of ether and chloroform upon the urinary functions would seem to indicate that there is not that objection to the use of ether that was formerly held to exist. At the same time, it is obviously important, when anæsthetising patients with advanced forms of kidney disease, to avoid prolonged etherisation, and to employ methods which will throw as little strain as possible upon the circulatory and respiratory functions. The liability of such patients to respiratory complications should be specially borne in mind. For further remarks see pp. 308 and 367.

[1] Mr. Woodhouse Braine believes (*Med. Soc. Proc.* vol. viii., 1885, p. 64) that there is greater risk of an epileptic attack being brought about by tooth extraction without an anæsthetic than when one is used.

[2] See an interesting and important paper by Dr. G. H. Savage—"The Relationship between the Use of Anæsthetics and Insanity" (*Lancet*, 11th November 1899).

I. DIABETES

Dr. Pavy, whose contributions to the subject of diabetes are so well known, has very kindly furnished me with his views as to the administration of anæsthetics to patients suffering from this affection. In cases "under control," in which sugar is at the time either absent from the urine or present only to a slight extent, he thinks that general anæsthesia is unattended by risk. But when the quantity of sugar in transit through the system is abnormally large, any profound disturbance of the vital processes, such as that attendant upon the use of an anæsthetic, especially for a protracted operation, may upset the balance, and lead to fatal diabetic coma. With such considerations before us it is clear that in the event of a diabetic patient requiring a surgical operation—(1) special attention should be paid to the diet for some time before the administration, with the object of reducing the quantity of sugar in the circulation; (2) the anæsthetic to be used should be very carefully chosen in order to lessen the chances of after-vomiting and other undesirable sequelæ; and (3) the administration should be as short as is compatible with the needs of the surgeon. Although I have not myself met with a case of diabetic coma after anæsthesia, I have been given brief notes of such a case by one of our leading surgeons. The patient suffered from diabetic boils, several of which had been incised without the employment of an anæsthetic. At 9.30 one morning, ether, preceded by nitrous oxide, was administered for further incisions; but the patient never recovered consciousness, and died at 4 P.M. the same day.

J. MENSTRUATION. PREGNANCY. LACTATION

It is customary not to operate upon patients during the **menstrual period**; but in cases of any urgency no hesitation need be felt in giving an anæsthetic. Whenever possible it is

best to wait. This is true even in the case of nitrous oxide, for patients may erroneously attribute disturbance of the menstrual function, etc., to the anæsthetic. Hæmorrhage after tooth extraction is said to be greater during menstruation than at other times; but this is doubtful.

I once observed very considerable hæmorrhage during and immediately after a nasal operation in a young woman in whom menstruation had been proceeding for forty-eight hours previously.

If an operation has to be performed during **pregnancy** an anæsthetic may unhesitatingly be given. No departure from ordinary rules is necessary during the earlier months; but during the later months care and discretion should be exercised. The diet of the patient should be cautiously regulated in order to avoid retching or vomiting after the administration. Nitrous oxide may be given with safety till the sixth or seventh month; but after that time it is probably better not to administer this anæsthetic, or, at all events, not to administer it in such a manner as to excite clonic muscular movements. I have given nitrous oxide and oxygen to a patient about thirty-five years of age who was within seven to ten days of her confinement. She experienced no after-effects of any kind from the anæsthetic. Laffont, quoted by Dr. Buxton, refers to a case of a female aged thirty-seven who was eighteen weeks pregnant when nitrous oxide was administered to her. Abortion followed, which he believed to be due to the gas having produced some asphyxial changes in the blood.[1] Chloroform, as is well known, is taken comfortably by pregnant women, when the pains of labour have to be relieved (see p. 179). But in the event of a surgical operation being decided upon during the latter months of pregnancy, I believe we should be consulting the safety of our patient best by administering a small quantity of the A.C.E. mixture, followed by ether, as directed on p. 413; or we might use this mixture throughout. Should ether produce respiratory difficulty, cough, etc., it should not be persisted in; but the mixture or chloroform substituted.

The use of anæsthetics during **lactation** in no way inter-

[1] *Brit. Journ. of Dent. Science*, 15th October 1898, p. 917.

feres with this process.[1] Indeed, as has been pointed out,[2] there is more likelihood of lactation being arrested by the performance of an operation without than with an anæsthetic.

[1] *Med. Chir. Trans.* vol. xlvii., 1864, p. 435.
[2] *Med. Soc. Proc.* vol. viii., 1885, p. 63.

CHAPTER VII

SPECIAL CONSIDERATIONS IN THE SELECTION OF ANÆSTHETICS AND METHODS (*continued*): (*b*) THE NATURE OF THE OPERATION, PROCEDURE, OR CONDITION FOR WHICH ANÆSTHESIA IS REQUIRED

GENERAL REMARKS

ALTHOUGH the selection of the anæsthetic should be chiefly regulated by the general state of the patient, the nature of the operation, procedure, or condition for which anæsthesia is to be induced should be carefully taken into consideration. There are, for example, certain operations which should unquestionably be performed under certain anæsthetics. Again, there is a tendency during some surgical procedures for circulation or respiration to become injuriously affected independently of the anæsthetic, and, unless the administrator be aware of such contingencies, he may erroneously attribute the phenomena to the action of the anæsthetic. And, lastly, when certain parts of the body are being manipulated or operated upon, there is need for a somewhat deeper or lighter anæsthesia, as the case may be, than is required under other circumstances.

Before proceeding to consider *seriatim* the various procedures for which a general anæsthetic may be required, it may be well to refer, in general terms, to the influence which—

(1) The posture of the patient; and

(2) The actual performance of a surgical operation

may have in modifying the usual phenomena of an administration.

(1) **The Effects which may be produced by Posture.**[1]—

[1] For fuller remarks see a joint paper by Mr. Marmaduke Sheild and the author "On Posture in its relation to Surgical Operations under Anæsthetics" (*Trans. Roy. Med. Chir. Soc.* 79, 1896).

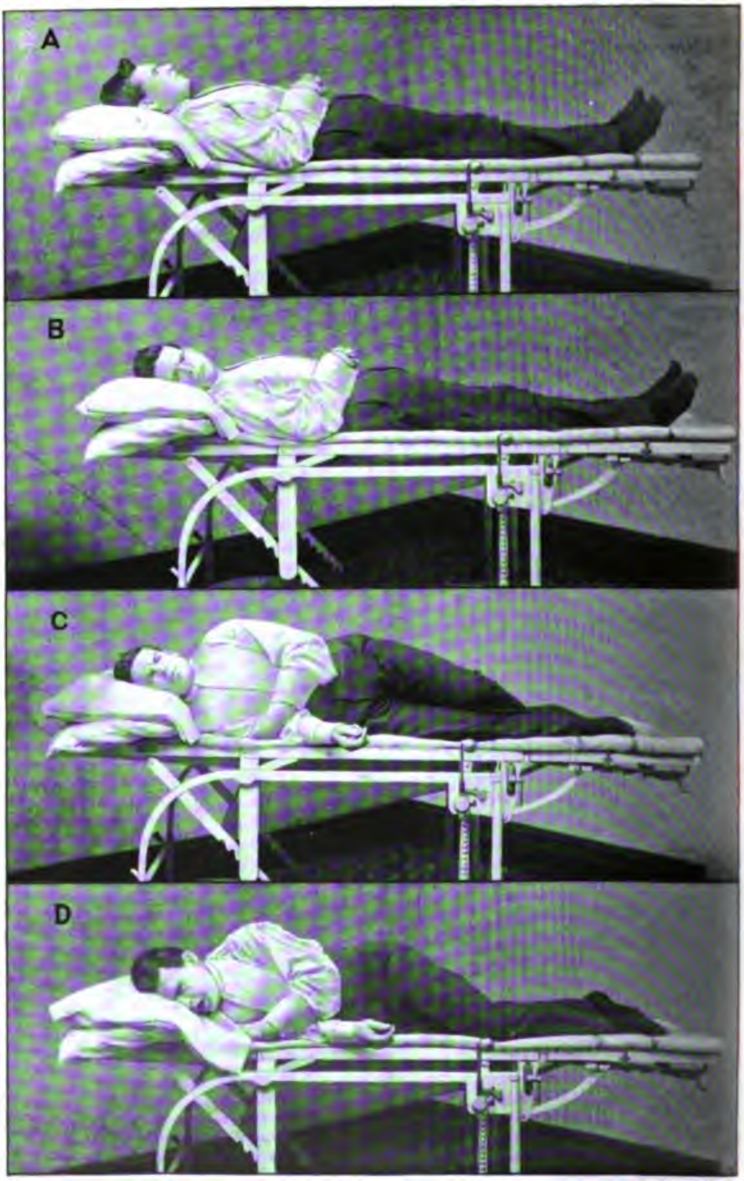


FIG. 6.—The Chief Surgical Postures. A, The Dorsal Posture: face looking upwards. B, The Dorsal Posture: face turned to one side. C, The Lateral Posture. D, The Latero-prone Posture. (Pages 138-39.)

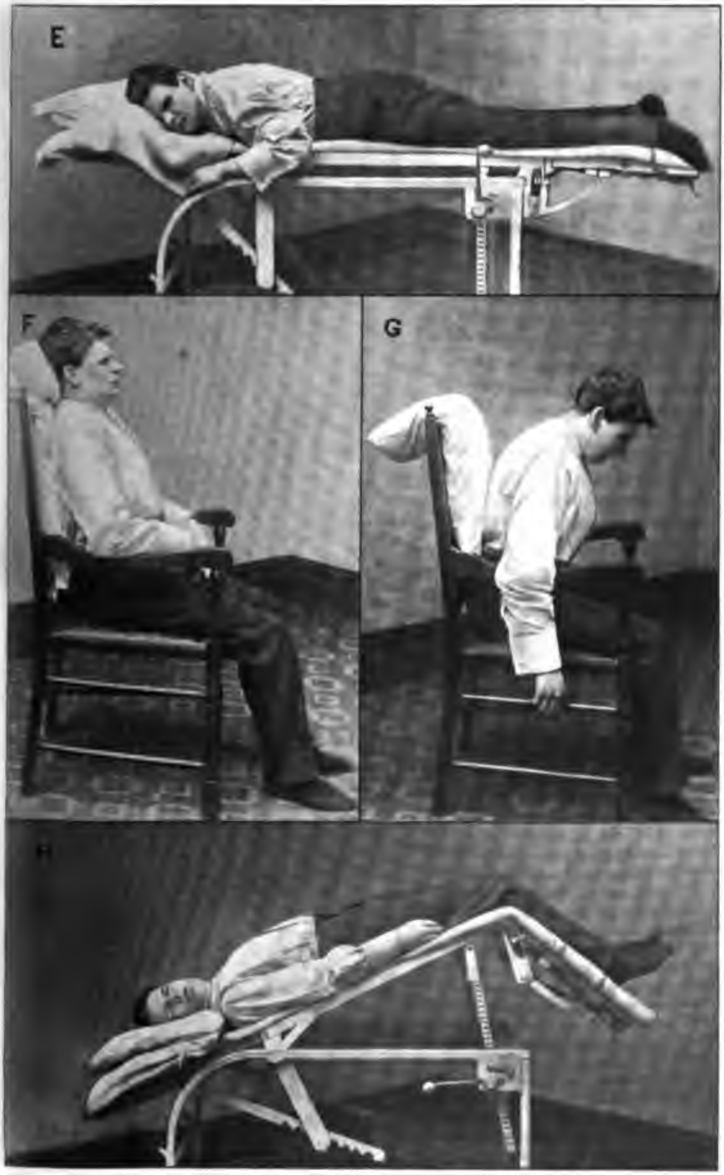


FIG. 6 (*continued*).—E, The Prone Posture. F, The Sitting Posture. G, The Bent-forward Posture. H Trendelenburg's Posture. (Pages 138-39.)

The posture of a patient prior to, during, and after the administration of an anæsthetic is a matter of greater importance than is generally imagined. It is perhaps not an exaggeration to say that twenty-five per cent of the difficulties encountered by inexperienced anæsthetists are referable, directly or indirectly, to this factor.

The posture of the patient *before* and *after* the administration is specially referred to in Chapters VIII. and XIX. respectively; the present remarks more particularly apply to posture *during* anæsthesia.

The chief postures now in use in surgical practice are shown in Fig. 6.

Faulty posture may (*a*) introduce undesirable complications into the anæsthesia; (*b*) render the performance of an operation difficult or impossible; or (*c*) lead to inconvenient or dangerous sequelæ.

(*a*) The efficient performance of **respiration** is to a great extent dependent upon proper posture. Thus, the position may be such that it favours the accumulation of mucus, saliva, vomited matters, or blood within and about the fauces. This is the explanation of the difficulties met with in anæsthetising semi-recumbent patients, the usual plan of turning the head to one side for the escape of mucus, etc., being inapplicable in this particular posture. Again, breathing will be liable to inconvenient modifications if the head be either flexed upon the sternum or extended upon the spine. When the head is thus flexed, the tongue tends to touch the pharyngeal wall, and obstructive stertor may thus arise. When the head is completely extended, the larynx is deprived of its natural protectors, the base of the tongue and the epiglottis, and swallowing becomes either difficult or impossible. This exposure of the laryngeal orifice is very likely to lead to abortive coughing, attempted swallowing, and numerous phenomena often erroneously attributed to other causes, and to favour the entry of foreign bodies into the larynx. There is yet a third way in which respiration may be directly interfered with by posture, viz. by the latter preventing free thoracic or abdominal movement. Thus, if the patient be placed in the latero-prone or prone posi-

tion,[1] and if care be not taken, the trunk weight may in certain cases tell injuriously upon lung-expansion, and an asphyxial state ensue. Sometimes this state comes about so insidiously that its true nature is completely overlooked. (See Illustrative Case, No. 41, p. 477.) In cases in which the diaphragm is much embarrassed by pressure from below, the purely dorsal posture may be impossible, at all events until the distension has been relieved, and anæsthesia may have to be induced with the patient in an almost vertical position. (See Illustrative Case, No. 17, p. 394.) Or, again, in unilateral empyema or pulmonary disease, great risk may be incurred by allowing a deeply anæsthetised patient to lie upon the sound side. Or, lastly, certain special postures, such as the so-called "lithotomy posture," may so impede breathing that it may be found impracticable to operate with the patient thus placed.[2]

With regard to **circulatory changes** dependent upon posture, these are, with rare exceptions, secondary to respiratory embarrassment. For example, the latero-prone or prone posture rendered necessary by the performance of such an operation as laminectomy may, more especially when chloroform is being employed, gradually bring about a state of asphyxia (often erroneously regarded as "surgical shock"), and this may easily lead to pallor and pulselessness. But a more or less vertical posture may, though only under certain circumstances, lead to symptoms of primary circulatory depression. Given that the patient's general condition is satisfactory, and that either

[1] The late Dr. Sheppard drew special attention to this point, and his observations are of considerable interest and value (see *Brit. Med. Journ.*, 11th July 1891, p. 68—"The Administration of Ether in Operations requiring the Lateral or Prone Positions," by C. E. Sheppard, M.D., F.R.C.S.). Dr. Sheppard says: "As regards actual clinical experience, I have twice met with cases where under chloroform an absolute cessation of respiration occurred as the direct result of impeded thoracic and abdominal movement in the semi-prone position; this was at once rectified by simply replacing the patient in the supine position, and thus removing the mechanical impediment."

[2] I have known this to occur in a case of excision of the rectum, in an elderly, obese, and breathless patient. The operation had to be performed in the lateral posture. Mr. Eve has kindly furnished me with the notes of a fatal case which occurred some years ago at the London Hospital. The patient, a man of forty-one, in a bad state of health from a neglected stricture, was anæsthetised with chloroform, and whilst being placed in the lithotomy position he suddenly became "blue" and ceased to breathe. Mr. Eve thinks that the additional strain thrown upon the right heart by raising the legs may have had a considerable share in the production of the syncope.

nitrous oxide or ether is employed, primary syncope due to a sitting posture is not to be apprehended, even though the anæsthetic be pushed. With regard to the vertical posture under chloroform, there can be no doubt that whilst it is as a general rule best avoided, its risks have been over-estimated. We should probably not be far wrong if we said that provided respiration be kept *absolutely* unembarrassed, and the anæsthesia be not too profound, chloroform may be given to sitting patients. At the same time it is not wise to adopt this course, except under special circumstances (see pp. 93 and 150); for should the circulation be feeble from pre-existing causes, or should it become so from surgical shock or too profound an anæsthesia, this posture may favour or actually lead to primary syncope.[1]

(*b*) Faulty posture may, by hampered respiration, **render certain operations difficult of performance.** Thus, in abdominal section, exaggerated, jerky, or "straining" breathing, arising from such causes, may greatly embarrass the surgeon. Or in operations performed with the patient in the latero-prone or prone posture, there may be considerable and inconvenient venous engorgement. But it is in operations upon the throat, nose, and upper air-passages that the question of posture is of paramount importance to the surgeon, and the reader is referred to the section dealing with these operations (p. 148) for further remarks.

(*c*) That posture during anæsthesia may be accountable for inconvenient or even dangerous **after-effects** there can be no doubt. In the surgery of the upper air-passages, for example, a faulty position of the patient may favour the entrance of foreign bodies, such as extracted teeth, blood, pus, etc., into the larynx, trachea, or bronchi; and affections of these parts, possibly of a fatal character, may ensue. Or the patient may be allowed to assume such a position that large quantities of mucus, saliva, or other fluids pass into the stomach and subsequently cause gastric disturbances of an

[1] Snow administered chloroform to 949 patients in the sitting posture and without any ill effects. He believed that, provided the ordinary means were adopted for the treatment of faintness, should it arise, there was no great objection to this position. He met with two or three cases, however, in which faintness came on in the sitting posture during recovery from chloroform.

aggravated character. Or, should faulty posture have kept up an impaired state of respiration for a considerable time, recovery from the effects of the anæsthetic will be less satisfactory than under other circumstances. And, finally, the maintenance of the patient's body, legs, or arms, for any great length of time, in certain constrained positions, may, more especially when "crutches," straps, wristlets, or other appliances have been used, bring about temporary or possibly permanent paralyses from injuries to nerves.[1]

(2) **The Effects which may be produced by the Operation itself.**—It is hardly necessary to point out that the usual phenomena of anæsthesia may be very materially modified by the surgical procedure for which the anæsthetic is given. The respiratory and circulatory changes thus induced may be of so slight and evanescent a character as to escape notice; or they may be so grave and persistent as to threaten the life of the patient. In many cases the symptoms may so closely resemble those produced by toxic quantities of the anæsthetic that the anæsthetist may easily be misled as to their real significance. Certain procedures will interfere primarily and perhaps exclusively with respiration; others primarily and nearly always exclusively with circulation.

(*a*) **Respiratory Phenomena.**—Generally speaking, respiration is deeper and quicker during the performance of a surgical operation than when no such stimulus to the respiratory centres is present (see p. 47). Putting on one side, as sufficiently obvious in their nature, those modifications and difficulties in breathing caused by surgical interference within and about the air-passages, there remain certain interesting cases in which respiration may become impeded or even arrested as the result of surgical procedures of a totally different character. These cases have already been discussed (Chap. III. p. 47).

(*b*) **Circulatory Phenomena.**—To the various forms of circulatory depression which may be brought about by the operation itself, the term "surgical shock" is conveniently applied. In the first place, profuse or protracted hæmorrhage may occur, and give rise to urgent or gradual symptoms of

[1] For further information see Chap. XIX. p. 499.

pulse-failure (see Illust. Cases, No. 42, p. 483, and No. 43, p. 483). Infants, very old persons, and anæmic and cachectic subjects are naturally more seriously affected by loss of blood than more vigorous persons. During the removal of large and vascular tumours, the excision of the upper jaw, and similar cases, the anæsthetist should narrowly watch the colour and pulse of the patient, and should not administer more of the anæsthetic than is absolutely necessary. The greater the quantity of blood lost, the less will be the quantity of anæsthetic required. Then we meet with certain cases, as important as they are interesting, in which, *independently of the anæsthetic, and independently too of hæmorrhage, or of prolonged surgical interference*, symptoms of cardiac depression, possibly of an urgent character, make their appearance. Transient cardio-inhibitory effects at the moment an incision is made or some other procedure carried out are not uncommon, more especially during a light anæsthesia under chloroform (see p. 347). In most cases the effect upon the circulation is so slight that it is not noticed; or, at most, a passing pallor is seen. But more grave symptoms may result. Mr. Bickersteth of Liverpool drew attention, as far back as 1853, to certain cases in which sudden cessation of the pulse was observed to occur simultaneously with the commencement of the operation[1]; and other observers have supported his contention, having reported cases in which, more especially during operations for strabismus, castration, and tooth extraction under light anæsthesia, sudden syncope has arisen. I have myself on many occasions met with undoubted examples of reflex cardiac

[1] See *Edinburgh Monthly Journal*, 1853, vol. xvii. p. 220—"On the Mode of Death from the Inhalation of Chloroform," by E. R. Bickersteth. After giving some very interesting experiments and clinical observations, Mr. Bickersteth says: "A peculiar and interesting fact, and one that I am inclined to think may account for many deaths, is, that in some individuals, when fully under the influence of chloroform, the pulse suddenly fails at the moment the first incision is made by the surgeon, and this, too, when the respiration is altogether natural." In support of this opinion three striking cases are quoted; in all of which, at the moment the incision for amputation of the thigh was made, the pulse suddenly ceased for several seconds. Two of the patients were markedly emaciated, and the other was probably feeble. In one of the cases the countenance became deadly pale, and breathing flagged during the cardiac depression; whilst in one of the others the respiration was unaffected, and very slight pallor was observed.

inhibition; and I believe that the true nature of such cases is frequently overlooked. It is difficult to say to what extent these reflex effects may be prevented by a deep anæsthesia. Given that consciousness has been destroyed, so that pain cannot be felt, the question arises whether these reflex phenomena are more likely to manifest themselves during the second than during the third stage of anæsthetisation. It has for many years been taught, in accordance with the theory referred to on p. 96, that surgical shock is most likely to occur during light anæsthesia, but my own experience leads me rather to the opposite conclusion. Some of the worst cases of surgical shock that I have seen have been in patients deeply anæsthetised, and I believe that the reason why the occurrence of this condition in deep anæsthesia has not been more frequently noticed is that the symptoms have often been erroneously attributed to other causes. Were the risk of what we now term light anæsthesia a tangible one there would be many more cases of syncope than there are. I am not, of course, referring to cases in which, through ignorance or other causes, the patient actually *feels* pain. It is quite conceivable, as in a remarkable case referred to by Lord Lister,[1] that death may take place at the commencement of an operation when the patient is more or less conscious. But when the stage of unconsciousness, excitement, and rigidity has come on, the commencement of a surgical procedure will almost invariably stimulate rather than depress both respiration and circulation, although, as Illustrative Case, No. 48, p. 486, shows, the reverse of this may obtain. There is another interesting argument in favour of what may be termed moderately deep as opposed to a very deep anæsthesia in cases specially liable to cardiac inhibition, viz. that when symptoms pointing to this condition have come on during an operation, the most successful treatment is to lessen the depth of anæsthesia (see p. 481). Of one thing I am perfectly certain—that it is a mistake to recklessly secure a very profound anæsthesia in all subjects with the object of avoiding surgical shock. The proper course is to be guided by the patient's general condition, obtaining as deep an anæsthesia as

[1] Holmes's *System of Surgery*, vol. iii. p. 600.

may be safely induced for the commencement of the operation, and then tending rather to a lighter degree as the operation proceeds. If patients be kept free from all reflex phenomena during grave operations, they will certainly be more prone to become collapsed than if a more rational and less heroic line of treatment be adopted, for the vaso-motor paralysis of profound narcosis will favour the accumulation of blood in the splanchnic area. Another interesting question in this connection is whether ether is more protective than chloroform against cardiac inhibition. My experience is certainly in favour of this view; for I have notes of several cases in which, during the use of chloroform, symptoms pointing to this state have arisen, and the patient has distinctly improved by substituting ether. In general surgical practice "shock" is often partly due to hæmorrhage and partly to cardiac inhibition, the anæsthetic having but a small share in the production of the symptoms, save in those cases in which too deep an anæsthesia has been obtained. In some instances vaso-motor paralysis undoubtedly plays a conspicuous part.

In Illust. Cases, Nos. 44 (p. 484) and 45 (p. 484), the changes in the circulation came on during operations upon the kidney; in Nos. 46 (p. 485) and 47 (p. 486), during long skin incisions for the removal of the breast; in No. 48 (p. 486), during the incision for a Syme's amputation in a feeble subject; in Nos. 49 (p. 487) and 50 (p. 488) during operations in the neighbourhood of the vagus in the neck; and in No. 52 (p. 489), in consequence of the entry of air into a vein. Although I have never seen an instance of the kind, cases have been reported in which syncope has taken place during the removal of fluid from the pleura. I have notes, however, of one case in which temporary cardiac depression took place when a distended bladder was suddenly emptied in the course of an operation for vesical calculus.

For further remarks on this subject the reader is referred to Chap. XVIII. p. 473, in which the treatment of surgical shock during anæsthesia is fully discussed.

A. OPERATIONS WITHIN OR ABOUT THE MOUTH, NOSE, PHARYNX, AND LARYNX (EXCLUDING THE EXTRACTION OF TEETH, SEPARATELY CONSIDERED)

Operations upon the Lips, Cheeks, Jaws, Tongue, Floor of the Mouth, Palate, Tonsils, Naso-pharynx, and Nose.—There is no branch of surgery in which the administration of an anæsthetic plays such an important part as it undoubtedly does in this. Twenty years ago delicate and prolonged operations within the oral cavity were not unfrequently abandoned owing to want of knowledge as to the principles upon which anæsthesia should be maintained. But with our present methods it is possible to safely and satisfactorily anæsthetise all patients requiring these operations, provided attention be paid to certain important details which may now be conveniently considered under the following heads:—

(1) The selection of the anæsthetic and the adjustment of the depth of anæsthesia.

(2) The posture of the patient and the avoidance of asphyxial complications from the entry of blood into the larynx and trachea.

(1) **Selection of Anæsthetics; Depth of Anæsthesia.**—When the operation can be performed within 30 seconds, a single inhalation of nitrous oxide (Part III. Chap. IX.) will suffice. When a trifle longer anæsthesia—from 30 to 45 seconds—is needed, nitrous oxide and oxygen (Part III. Chap. IX.) may be advantageously chosen. When a total available unconsciousness of from 45 seconds to 5 or even 10 minutes is required, *a single administration* of ether (preceded if possible by nitrous oxide or A.C.E. in order to prevent the initial unpleasantness of the ether) will meet the case. When the operation is of such a nature that a more protracted unconsciousness is essential, the anæsthesia thus induced by ether should be subsequently maintained by means of chloroform. Some surgeons prefer chloroform throughout, or the A.C.E.-chloroform sequence, for these operations, and there is doubtless much to be said for this preference, particularly in cases in which hæmorrhage may inconvenience the surgeon (as in

cleft-palate and nasal operations), but there are so many advantages in the system here recommended that I venture to give it the first place. The particular operations which may be successfully performed under the above anæsthetics and sequences of anæsthetics will appear in the subsequent parts of this section. It is only necessary at this point to draw attention to one great advantage of ether in mouth and nose operations, viz. that the patient can be safely "charged up," so to speak, by considerable quantities of its vapour, so that when the inhaler is withdrawn there is not that tendency to inconvenient recovery during the necessary initial manipulations of the surgeon which is so common when other anæsthetics have been used. I have, for example, on more than one occasion, given a patient so much ether in the first instance that the surgeon has been able to remove the tongue or upper jaw without any more anæsthetic being required. There is, however, no great point in these single and protracted ether administrations; for nothing can answer more admirably than does the ether-chloroform sequence (Part III. Chap. XIV.) in this branch of surgery. Nor is there much to be gained by repeated reapplications of ether in mouth and nose cases, although this system may be safely adopted if desired. The ether-chloroform sequence is seen to its best advantage when the chloroform anæsthesia is only moderately deep, and it is precisely this form of anæsthesia which should be maintained in most operations of this group. With regard to the point at which the change from ether to chloroform should be effected, it may be said that, putting exceptional cases on one side, the best plan is to proceed as follows:—(1) To place the patient deeply under ether; (2) to suspend the ether administration and to allow a *slight* tendency towards recovery, *i.e.* the re-appearance of slight conjunctival reflex, cough, or swallowing; (3) to subdue this tendency by cautiously administering chloroform: (4) to allow the operation to begin as the reflexes again disappear; and (5) to keep up, from this point, only a *moderately* deep chloroform anæsthesia. The late Mr. J. Mills[1]

[1] *Lancet*, 14th December 1878, p. 839. Mr. Mills found, and I can corroborate his statement, that it is not always easy to keep up anæsthesia by this means in alcoholic subjects.

was, I believe, the first to use Junker's inhaler (p. 315) for maintaining chloroform anæsthesia in these cases. Before changing to chloroform, the anæsthetist should ascertain whether respiration is taking place through the mouth or nose. It is obviously next to useless to insert the tube of Junker's apparatus into, or place lint sprinkled with chloroform over the mouth, when respiration is taking place through the nose. Generally speaking, it is best to pass a flexible silk catheter of fairly large bore through the anterior nares so that its free end may be felt just beyond the soft palate. It is easier to maintain anæsthesia by this means than by the use of a mouth tube. Should the anæsthetist prefer the latter (p. 320) he must be careful to see that respiration is oral, and if necessary the anterior nares should be plugged with lint. As regards the depth of anæsthesia during the chloroformisation, it may be said that, putting aside such delicate operations as those for cleft-palate, slight phonation, occasional cough, and frequent swallowing movements are to be encouraged, provided they be not accompanied by movement. Towards the end of these operations, however, when much blood has been lost, very little of the anæsthetic will be required. As a rule, the greater the hæmorrhage the lighter should be the anæsthesia.

When the actual or the galvano-cautery has to be used, ether must be avoided owing to the inflammable character of its vapour. There is, however, no objection to placing the patient under ether and then changing to chloroform, but the cautery should not be used till two or three minutes after the change. Deep anæsthesia is needed in order to ensure perfect quietude.

(2) **Posture; Avoidance of Blood entering the Larynx and Trachea.**—A smooth and successful anæsthesia can only be secured in cases of this group by careful attention to the posture of the patient. In addition to the remarks which have already been made upon this subject (p. 138), there are certain special considerations which apply to mouth, nose, and throat operations. The following are the postures in which these operations may be and are performed:—

(i.) *The dorsal, with the head neither flexed nor extended;*

(ii.) *The dorsal, with the head completely extended over the end of the table or couch;*

(iii.) *The dorsal, with the head turned to one side;*

(iv.) *The dorso-lateral, with one shoulder raised, and with the head turned to the opposite side;*

(v.) *The purely lateral;*

(vi.) *The latero-prone, with the face pointing downwards towards the floor;*

(vii.) *The semi-recumbent or "propped up" posture, with the head in the body axis,* i.e. *neither flexed nor extended;*

(viii.) *The semi-recumbent or "propped up" posture, with the head extended over the pillow;*

(ix.) *The sitting;*

(x.) *The "bent forwards"; and*

(xi.) *Trendelenburg's posture.*

Most of these are figured on p. 138. If posture (i.) be adopted, care must be taken to have at hand several small coarse sponges, unattached to holders, for keeping the fauces free from blood; the anæsthesia should not be profound; and if the hæmorrhage be excessive, the head must be frequently turned to one side. Posture (ii.) is in my opinion and experience open to much objection. It renders swallowing and coughing difficult or impossible; it increases the hæmorrhage by retarding the flow of venous blood from the head; and if the nasal channels be blocked, it does not always provide that free drainage for blood which is the main object of the posture. If it be adopted, the anæsthesia should be deeper than is advisable in other postures; otherwise inconvenient and abortive attempts at swallowing and coughing may complicate the case. Posture (iii.) is not nearly so satisfactory as posture (v.). Seeing that in each case the head is on the side, there is no advantage in the body being supine. In other words, if the operator can operate with the head on the side, the trunk should be placed upon the side also. Some surgeons[1] favour the fourth posture, especially for cases in which it is important that a good view of the palate, tongue, or fauces should be obtained, and it is certainly very useful when the purely lateral posture would be inconvenient. Of all postures, however, the lateral is undoubtedly the best so far as the anæsthetist is con-

[1] Mr. Stanley Boyd employs this posture for operations upon the jaws, tongue, and naso-pharynx.

cerned. The patient should be placed strictly upon his side, with his legs flexed and with one cheek resting on the pillow, the open mouth being turned so that it directly faces a window. Owing to the facility with which all blood flows out of the mouth, sponging is generally unnecessary; and it is possible to keep up a deep and uninterrupted anæsthesia throughout by means of Junker's inhaler. The next posture (vi.) is usually inconvenient to the surgeon, and has no advantage over the purely lateral. Of the two semi-recumbent or "propped up" postures (vii. and viii.) that in which the head is not extended is the better, but both are open to considerable objection from the anæsthetist's point of view, for when patients are thus placed, all blood must, of necessity, drain backwards, and turning the head to one side does not permit the blood to escape as it would if the patient were flat. So far as the surgeon is concerned, posture (viii.) is an admirable one in tongue, jaw, and other cases; but it is practically impossible for the anæsthetist, however skilled he may be, to maintain that unembarrassed form of anæsthesia which may be depended upon in other postures. With regard to (ix.), the sitting posture, there can be no doubt that for many rhinological and other operations of this group it is, from the operator's standpoint, exceedingly convenient. It is universally admitted that there is no risk of administering nitrous oxide or ether to sitting patients, but the question arises, Are we justified in employing chloroform? I think the proper answer to this question is to be found in the following considerations, viz. (1) that it is certainly unwise for any one to administer chloroform *ab initio* to patients thus placed, although there are certain exceptional cases in which this plan must be followed[1]; (2) that unless the administrator has had a large experience in giving anæsthetics, it is not advisable for him to give any other anæsthetic than nitrous oxide or ether to sitting patients; but that (3), provided the anæsthetist be thoroughly experienced, there is no objection to his first placing a sitting patient well under ether in the manner already described (p. 147) and continuing the anæsthesia by means of chloroform. In conducting such cases the anæsthetist must keep the patient's head, as

[1] As in operating for laryngeal growths in children. See p. 160.

far as possible, in a line with the body; he must maintain only a moderately deep anæsthesia; and should hæmorrhage be free, he must either tilt the patient's head and body forwards from time to time, or see that the blood is removed by frequent sponging. The "bent-forwards" posture (x.) may be employed when the natural or artificial nail is used for removing post-nasal vegetations. The patient is first placed under ether in the dorsal or sitting posture, and bent forwards during the scraping process. Sir William Dalby[1] advocates this position, and it certainly has the merit of preventing blood from embarrassing respiration: but as this can be equally well accomplished in the lateral posture, this is generally preferred by surgeons. The last posture (xi.) to be considered is that known as Trendelenburg's. Its advantage in these cases is that it provides for the flow of blood away from the larynx, but it has the drawback that it undoubtedly favours hæmorrhage. It is, however, useful in hare-lip cases in children; and some surgeons speak well of it for cleft-palate operations.[2]

The entry of blood into the larynx and trachea during these operations may be easily avoided by attention to the following simple rules:—(*a*) When practicable, the posture should be such that blood can easily flow out of the mouth; (*b*) the head should be kept, as far as possible, in a line with the body, so that coughing and swallowing movements may effectually take place; (*c*) the anæsthesia should not be too profound, otherwise the pharyngeal and laryngeal reflexes will be abolished; and (*d*) the anæsthetist should have at hand several small, round, coarse sponges unattached to holders, so that, in the event of it being impracticable to adopt a posture favourable for the escape of blood, this fluid may be repeatedly removed by sponging. The cases in which asphyxial complications from blood are most to be feared are those in which the larynx has become, during the course of chronic throat or nose disease, comparatively insensitive. In such cases coughing and swallowing may not take place even during a comparatively

[1] "Adenoid Growths in the Pharynx," *Lancet*, Oct. 1886, p. 618.

[2] Keen of Philadelphia advises this posture for operations upon the naso-pharynx (*Annals of Surgery*, 1897, p. 97).

light anæsthesia, and if the posture be faulty a moist expiratory râle will become audible, indicating that blood is present in the larynx. The treatment of this condition is considered on p. 452. For operations in the dorsal, the semi-recumbent, and the sitting postures, a widely-opening Mason's gag (Fig. 7, p. 198) generally answers well enough; and one fitted with tubes for transmitting chloroform vapour may be employed if desired. But when the lateral or latero-prone posture is employed a Mason's gag may be out of the question, and it is best under these circumstances to insert a dental mouth-prop (Fig. 13, p. 201) between the teeth or gums of the side next the pillow; to employ the long screw-gag shown in Fig. 44, p. 322; or the little appliance of Fig. 45, p. 323. Difficulty may often be experienced in maintaining breathing with the mouth widely open, for the tongue may be thus thrown against the pharyngeal wall. By forcing the chin away from the sternum and relaxing the gag slightly, such difficulties usually disappear. A very small Mason's gag is essential for children, and generally answers better than any other for operations upon the palate. After operations of this group the gag should be relaxed, but not removed till distinct signs of recovery take place.

In operations upon the **lips** and **cheeks** the lateral or dorso-lateral posture will give the best results. The "propped up" position, with the head extended, is likely to lead to difficulties. For **hare-lip** operations the infant's body should either be placed in Trendelenburg's posture or it should be semi-inverted by means of pillows, chloroform anæsthesia being kept up either by pumping the vapour through the tube of a Junker's inhaler held several inches away from the mouth, or by a Skinner's mask or lint held horizontally above the site of operation. It is well to keep a finger upon the radial pulse in these cases, unless other indications are present as to the depth of anæsthesia.

For operations upon the **jaws** the lateral or dorso-lateral posture is again to be recommended. I have on more than one occasion known the superior maxilla to be removed from a patient lying upon the side without it being once necessary to sponge out the fauces. Operations upon **the antrum** are certainly

conveniently performed with the patient lying upon his non-affected side in the strictly lateral posture facing a good light. The mouth should be kept slightly open by means of one of the dental mouth-props shown in Fig. 13, p. 201, or by the chloroform prop of Fig. 45, p. 323, as Mason's gag is inapplicable. When the prop has been inserted the operation may be begun, and if swallowing and slight coughing be not abolished, sponging will be rarely if ever needed even though hæmorrhage be very free. There is often a good deal of bleeding in these cases, and if the dorsal posture be adopted difficulties will almost certainly arise.

For operations upon the **tongue** the lateral or latero-prone posture is the best, although the "propped up" position is still used by many surgeons. Deep anæsthesia should be secured, as already indicated, before the gag and nose tube are inserted. When the first part of the operation consists of tying the lingual arteries or removing affected glands, the anæsthetist's task will be easier than under other circumstances; for there will be no inconvenient tendency for the patient to recover from the effects of the anæsthetic during the insertion of the gag, etc. When a considerable portion or the whole of the tongue has been removed, the breathing may become embarrassed by the stump of the tongue and epiglottis covering the opening of the larynx. Many surgeons follow the plan of passing a ligature through the base of the organ and epiglottis before excision, in order to avert this danger; and the anæsthetist will probably be excused for suggesting the precaution, should it have been omitted. In connection with these operations it may be well to say a few words as to the advisability of tracheotomy, for the anæsthetist may be consulted upon this point. Generally speaking, this measure is unnecessary if the lateral posture be adopted. But, should the patient display any considerable embarrassment in breathing when the mouth is first opened to the requisite extent by the gag, it is, as a rule, advisable to open the trachea at this juncture, for such embarrassment to breathing will be liable to increase during the course of the case.

In **staphylorrhaphy** and other operations upon the **palate** the administration of ether before chloroform is, by some

surgeons, regarded as open to objection owing to the inconvenient hæmorrhage which may result. To meet this objection the A.C.E. mixture may, if desired, be used to precede chloroform, or the latter may be employed throughout.[1] The advantages of initial etherisation are, however, as great in these cases as in others of the group, so that, unless special circumstances be present, the "gas"-ether-chloroform or the A.C.E.-ether-chloroform sequence may be advantageously chosen. The dorso-lateral posture with the head slightly extended answers very well. Many operators, however, require the patient to be placed in the semi-recumbent position with the head thrown back. Generally speaking, the anæsthesia must be profound in order to avoid retching, coughing, or movement. But in the earlier stages of staphylorrhaphy, when hæmorrhage is free, it is usually advisable to maintain only a moderate degree of anæsthesia. One advantage of the dorso-lateral posture is that the head can be occasionally turned well to the side for the escape of blood, should bleeding be profuse. In the later stages of the operation, when the sutures are being introduced, deep anæsthesia may be again produced. It is necessary to watch the pulse in most cases whilst working with a very profound narcosis. The effect of the chloroform upon the circulation may be the chief guide to the anæsthetist. Considerable cyanosis, with pallor, half-open lids, and coldness of the face and extremities are common accompaniments of the anæsthesia.

I have administered anæsthetics for the **removal of the tonsils** in all possible ways, and the following I believe to be the best. The patient is placed in the dorsal posture, and ether is administered, preceded by nitrous oxide or the A.C.E. mixture, till the conjunctivæ have been insensitive for some minutes. He is then propped up, almost vertically, by means of pillows; his mouth is opened by a Mason's gag; and his head adjusted so that a good view is obtained by the surgeon. Or if preferred the sitting posture may be adopted from the

[1] Mr. William Rose (*On Hare-lip and Cleft-palate*, 1891, pp. 105, 106) gives some excellent directions for the regulation of the anæsthetic. Mr. Rose advocates the use of chloroform throughout for these cases; and urges that it is best administered upon a towel drawn through a safety-pin. He objects to any nasal or buccal tubes for the administration.

commencement, and "gas and ether" given. When the tonsils have been removed the head may be bent forwards for the escape of blood. Should more anæsthetic be needed, the ether inhaler may be safely reapplied if the head be vertical or bent forwards and the gag be *in situ;* or, as already mentioned, chloroform may be substituted. Many operators prefer nitrous oxide, the anæsthesia of which is best obtained by administering the gas with oxygen (p. 251). In this event one of the mouth-props of Fig. 13, p. 201, should be first inserted and "gas and oxygen" given as for a dental operation. The removal of tonsils under ether is exemplified in Illustrative Case, No. 24, p. 416.

The part played by the anæsthetist in operations for the **removal of post-nasal adenoid growths** is one of no small importance; and as the most divergent views exist not only with regard to the means which should be adopted for inducing and maintaining anæsthesia, but as to the posture in which patients should be placed, the subject deserves special consideration. With the actual surgical details of the operation we are not, of course, concerned. It may be said, however, that from the anæsthetist's point of view surgeons divide themselves into two classes—those who perform the operation as quickly as possible; and those who see no necessity for, or advantage in, this rapidity. It would be out of place to express an opinion on the respective merits of these two schools, but speaking purely as an anæsthetist, I must confess that the deeper and more persistent anæsthesia required by the latter system is more in harmony with the general principles which should guide us. It is certainly more satisfactory to the administrator of the anæsthetic to rapidly induce insensibility and to maintain this condition till the operation is completed (which can be done with safety) than to adopt methods which may favour the occurrence of screaming, inconvenient movement, and other unpleasant or even distressing symptoms. It is only fair, however, to admit that the transient and light anæsthesia which many surgeons prefer has the advantage of leaving the patient with little or no after-effects. But the inconvenience of this partial narcosis, and the distress to the friends which it may occasion, are

certainly, to my mind, open to great objection. Were there any real danger in keeping up a proper degree of anæsthesia, the whole aspect of the question would be changed, but this is not so when proper principles are followed and the administration is skilfully conducted. The selection of the anæsthetic will necessarily largely depend upon whether the operation is to be of the rapid or the deliberate kind. If the former, a single administration of nitrous oxide (preferably mixed with oxygen) may be all that the surgeon needs; or nitrous oxide supplemented by a short inhalation of ether may meet his requirements; or a short administration of chloroform, A.C.E., or ether may be conducted till the signs of surgical anæsthesia manifest themselves, when the operation may be begun. In the case of nitrous oxide, either a small dental mouth-prop should be placed between the teeth during the inhalation, so that no delay need arise in subsequently opening the mouth by the Mason's gag, or the Doyen's gag shown in Fig. 25, p. 264, may be inserted before the inhalation commences. For the deliberate and more lengthy operations, the plan I usually adopt is to administer nitrous oxide and ether till the patient has just lost his corneal reflex; a Mason's gag is then inserted; the operation is begun; and should further anæsthesia be desired, it is maintained by pumping in chloroform vapour through an oral tube, the patient being kept just sufficiently "under" to cough and swallow. For children under four or five years I use the C.E.-chloroform sequence, or give chloroform throughout. Whenever possible, however, nitrous oxide should be given, as it prevents, or rapidly cuts short, all crying or struggling—an important consideration when relatives are near. The best plans of giving "gas and ether" to children and adults are described respectively on pp. 404 and 407. With regard to the vexed question of posture the reader is referred to what has been said above (p. 149). The purely dorsal posture, although regarded by many as dangerous, is in reality a good one provided the depth of anæsthesia be adjusted as just recommended; that blood be repeatedly sponged away by small, coarse, unattached sponges; and that, should hæmorrhage be excessive, the head be turned occasionally to the side for drainage. The dorsal posture with the head

extended over the end of the table, although popular, is not as satisfactory as other positions (p. 150). The dorso-lateral posture, with one shoulder raised and with the head turned to one side and slightly extended, is employed by many surgeons, and is certainly preferable to the last mentioned. The semi-recumbent or "propped up" posture with the head neither flexed nor extended is not a good one, for reasons already given (p. 150). The "propped up" posture with the head extended is so unsatisfactory that nothing need be said about it. There are, however, certain points in favour of the sitting posture in these cases. It is certainly a very convenient one for the surgeon; and so long as the principles already laid down (p. 151) are followed, a skilful anæsthetist will be able to steer his patient perfectly through even a protracted operation. The "bent-forwards" position is only applicable under the circumstances already referred to on p. 151. And Trendelenburg's position is open to the objection that it is inconvenient to the surgeon, and is liable to lead to unusual hæmorrhage. Whatever posture be adopted, the patient should, immediately the operation is finished, be placed upon his side with the mouth *slightly* opened by a Mason's gag: and he should not be left until distinct evidences of recovery are present.

In all **nasal operations**, such as those for removal of **nasal polypi, the turbinated bodies, "spurs,"** etc., it is a good plan to have the mouth slightly or widely opened by a gag, not only because of the greater ease by which a chloroform tube may, if required, be passed to the back of the throat, but because of the facility afforded for sponging away blood when necessary. Patients requiring operations within the nasal cavities often possess a partially or wholly occluded nasal air-way; and in such patients it is a good plan to place a little mouth-prop (Fig. 10, p. 199) between the teeth before commencing the administration. This is particularly important in muscular subjects, in whom masseteric spasm is likely to be pronounced. For several years I have been in the habit of giving anæsthetics for these operations with the patients in the sitting posture, and with very satisfactory results. It must be borne in mind, however, that considerable practice is necessary before attempting this procedure, and in the absence of that experience

the lateral, dorso-lateral, or the dorsal posture should be chosen. Very free hæmorrhage may be met with after the removal of the turbinated bodies or "spurs," so that special care must be taken to avoid blood entering the larynx (p. 152).

For all other operations within and about the naso-pharynx and pharynx, such, for example, as those for the removal of **naso-pharyngeal polypi** or **tumours of the epiglottis,** the anæsthetist should proceed as has been above indicated, employing the lateral or dorso-lateral posture whenever possible, and regulating the depth of anæsthesia as described.

Operations within and upon the Larynx and Trachea.—The administration of anæsthetics for these operations is often a rather anxious task, because of the condition of the patient at the time. Speaking generally, chloroform, or some mixture containing chloroform, is preferable to ether. But unless marked difficulty in breathing exist, a small quantity of ether, as in the A.C.E.-ether-chloroform sequence, is advantageous early in the administration.[1]

For such operations as partial or complete **excision of the larynx, thyrotomy for the removal of laryngeal growths,** etc., the surgeon usually first performs tracheotomy, employing a Hahn's or Trendelenburg's tube with the object of preventing blood passing from the larynx to the trachea. In my experience Trendelenburg's plan of cutting off communication with the trachea by the distension of a small air-ball round the tracheotomy tube has given the best results. In one or two cases I have known the sponge surrounding the Hahn's tube to allow the passage of blood from above downwards. But whichever plan be chosen, it is certainly a mistake to adapt to the tracheotomy tube the long flexible tube and funnel generally supplied for maintaining anæsthesia; for the additional tube greatly impedes breathing and tends to become choked by blood and mucus. The simplest plan is to maintain anæsthesia by a Junker's apparatus, employing a small silk catheter, the end of which is passed a short distance down the tracheotomy tube. Apnœic pauses and almost im-

[1] Mr. Butlin, whose experience in these operations is very large, holds this view.

perceptible breathing are commonly met with immediately after the introduction of the tracheotomy tube. It is advisable to keep up as deep an anæsthesia as possible in order to prevent reflex cough and movement. Some surgeons employ an ordinary tracheotomy tube in these cases and insert a small sponge, directly the larynx has been opened, in such a way as to prevent blood passing towards the trachea. There are practically only two postures available for these operations—the dorsal with the shoulders slightly raised and the head somewhat extended, and that of Trendelenburg, already referred to. The former, which is generally chosen, is not a good one from the anæsthetist's point of view; for should the patient's breathing have been embarrassed before the administration, this embarrassment may increase to such a degree when the head is thrown back that anything like complete extension may be impracticable. The convenience of the anæsthetist must, however, give way to that of the surgeon.

When Trendelenburg's posture is employed, precautions against blood entering the trachea need not be taken, and chloroform anæsthesia can be very efficiently kept up without in any way interfering with the manipulations of the surgeon, by holding a Skinner's mask, well charged with chloroform, horizontally and directly *above* the site of operation.[1] The neck being at about an angle of 45°, the operator will have no difficulty in working under the horizontally-placed mask, the side of which will touch the patient's sternum.

Although **intra-laryngeal operations** are now generally performed under cocaine, it is necessary to administer a general anæsthetic in the case of children; and no other agent than chloroform is applicable. The child should be carefully anæsthetised in the dorsal posture, and when moderately deep anæsthesia has been secured, placed in a chair with the head very slightly thrown back. A Mason's gag is next inserted, the mouth-tube of Junker's inhaler intro-

[1] I have assisted Mr. Eve at several of these operations in which he has placed his patient in Trendelenburg's posture, and he finds it very advantageous, the only inconvenience being that there is rather more hæmorrhage than usual.

duced, and the operation begun. Considerable experience in anæsthetics is needed before cases of this kind can be undertaken; for the anæsthetic has to be given till reflex coughing or movement cannot take place, and yet it must not be pushed to the degree of causing such a fall of blood-pressure as would be hazardous in the sitting posture. It is in these cases that the plan suggested and practised by Dr. Scanes Spicer,[1] of spraying the fauces with a dilute cocaine solution, is of great service; for it allows of a lighter general anæsthesia than would otherwise be possible. The cocaine not only lessens irritability but also hæmorrhage and salivation. I have administered chloroform in conjunction with cocaine on many occasions, and can speak well of the plan. The pulse should be carefully watched throughout.

For **laryngotomy** and **tracheotomy** chloroform is also the best anæsthetic. It should be given throughout in all cases in which difficult breathing pre-exists; but when no such difficulty is present there is no objection to precede the chloroform by A.C.E. and ether, or "gas and ether," as already indicated. The remarks just made as to the posture of patients for thyrotomy apply here. Directly the larynx or trachea has been opened, the breathing (which may have been more or less embarrassed up to this moment) usually undergoes a peculiar change. When the coughing excited by the introduction of the tube has subsided, it often becomes shallow, and even ceases for considerable periods, after which, however, the respiratory mechanism seems to get accustomed to its altered circumstances, and the apnœic pauses disappear.

The Use of Morphine prior to Ether or Chloroform.—This plan is regarded by many Continental surgeons as specially advantageous in major operations within the mouth or nose, owing to the very small quantity of the anæsthetic needed to keep up anæsthesia, or, more correctly speaking, analgesia. For remarks on this mixed narcosis, see Part III. Chap. XV. p. 422.

[1] See *Brit. Med. Journal*, vol. ii., 1894, pp. 1171 and 1276.

B. THE EXTRACTION OF TEETH

Choice of Anæsthetics, etc.—The best anæsthetic for use in dental surgery is undoubtedly **nitrous oxide.** It is true that the resulting anæsthesia after the inhalation of this agent is of very short duration; but this disadvantage is fully compensated for by the fact that the return of the patient to consciousness is, with the rarest exceptions, unattended by those discomforts which often follow the use of other anæsthetics. This absence of after-effects is dependent upon the inhalation being necessarily short, owing to want of free oxygen. The great error with regard to the use of nitrous oxide in dental surgery is that too long an operation is often attempted. The period of deep and true anæsthesia from nitrous oxide is short, and it is often impossible, even though the gas be freely pushed, to extract more than one tooth, without the patient indistinctly knowing something of what is going on. Our aim should be to keep the patient's mind a complete blank during the operation. Unpleasant dreams, shrieking, etc., are usually the result of the operator proceeding with his duties during imperfect anæsthesia. It is far better for a patient to inhale nitrous oxide on two or more occasions, and to have comparatively little done at each sitting, than for him to experience the distress of partial anæsthesia.

Whether nitrous oxide should be administered *per se* or with air, or oxygen, is a matter which will be discussed in Chap. IX. p. 261.

Whilst no anæsthetic is at present known which can compare with nitrous oxide, with or without oxygen, for dental operations lasting from twenty to forty-five seconds, differences of opinion exist as to the most suitable anæsthetic when unconsciousness of about twice this duration is required. An average operator can extract two teeth or roots of average difficulty, in an average patient, who has been placed fully under nitrous oxide, without the patient experiencing any pain or disagreeable sensation. But suppose three or four teeth more or less firmly rooted have to be removed at one

sitting, what plan should be adopted by the administrator? Several courses are open to him. He may administer **oxygen with nitrous oxide** (p. 251) for a period of about three minutes, and in most, but not in all subjects, an anæsthesia will be obtained which will meet the case. Or he may administer nitrous oxide as fully as possible, and in the event of the anæsthesia being of insufficient duration, he may **reapply the face-piece** before consciousness returns; or he may allow the patient to return to consciousness and then **repeat the inhalation**; or he may keep up nitrous oxide anæsthesia **during** the operation (p. 243); or lastly, he may prolong the anæsthesia of nitrous oxide by the addition of a small quantity of **ether** vapour (Part III. Chap. XIV.). Should the nature of the operation be such that the patient's head can be arranged and kept vertically in the chair, the second plan may be chosen, because the blood which has escaped during the first half of the operation will, in the vertical position of the head, flow into the floor of the mouth and not to the back of the throat. This reapplication of nitrous oxide, if quickly carried through, and if unattended by the swallowing of blood, rarely leads to any after-discomfort of the patient. A double administration, however, with an interval of consciousness, is more frequently followed by retching or vomiting, more especially if food be present in the stomach. The chief objections to the continuous administration of nitrous oxide are considered on p. 243.

The addition of what is known as a "whiff" of ether to nitrous oxide answers well when the operation is performed five hours after a light meal, and when care is taken to prevent blood from being swallowed during or immediately after the operation. But it must not be forgotten that disagreeable after-effects such as nausea and headache are a trifle more common. after a small quantity of ether than after a double administration of nitrous oxide.

It is hardly necessary to point out that, whilst in some cases a dozen or even more teeth may be removed under a single administration of nitrous oxide, one tooth or root may present such difficulty in extraction that the most profound degree of etherisation for several minutes or longer may be necessary. But as it is almost impossible to say with cer-

tainty what length of anæsthesia will be required for an apparently difficult dental operation, I am of opinion that the patient should, in the first instance, be given the chance of having the tooth or teeth removed under nitrous oxide. It is unsatisfactory to have induced a deep ether anæsthesia for a tooth supposed to be liable to present great difficulties in its extraction, and to find that it could easily have been removed under nitrous oxide.

Chloroform should never be used in dental practice save in those highly exceptional cases in which neither nitrous oxide nor ether can be given.[1]

Children.—Children generally take nitrous oxide well; but as they rapidly recover from its effects, and are more susceptible than adults to muscular twitchings ("jactitation"), the painless extraction of teeth under the influence of this anæsthetic is not always an easy matter. The anæsthesia produced by nitrous oxide in the presence of oxygen is more satisfactory in its nature than that of nitrous oxide alone, as it gives longer time to the operator, and is unattended by jactitation. If anything more than a very short anæsthesia be required, the administrator will do well to place the little patient under ether, preceded by nitrous oxide or the A.C.E. mixture, as described on pp. 404 and 416. In employing nitrous oxide for children, it is a good plan to warn the friends of the possibility of the occurrence of screaming, a not unfrequent reflex phenomenon in these subjects.

Posture.[2]—The anæsthetist should see that his patient is comfortably seated in the operating-chair. His legs should be so adjusted that, in the event of movement or opisthotonic rigidity occurring, the feet cannot become entangled in the foot-rest, or the heels used for supporting the arched body.

[1] For full details on this subject see a paper read by the author at the annual meeting of the British Dental Association at Edinburgh, August 1895, entitled, "An Inquiry concerning the Safety and Sphere of Applicability of Chloroform in Dental Surgery" (*Journal British Dental Association*, 1895, p. 660). Although the facts brought forward in this paper were strongly condemnatory of the practice of giving chloroform in dental surgery, it is a lamentable fact that the practice still continues, and, as a consequence, frequent fatalities are reported.

[2] For special remarks on posture during these operations (with figures illustrating good and faulty positions), see an article by the author in the *Journ. Brit. Dental Assoc.* for 1896, p. 645.

The patient's head should be in a line with the body, and as vertical in the chair as is compatible with the convenience of the operator. When the head is thus placed blood will flow to the floor of the mouth; the tongue will not tend to gravitate backwards; stray teeth, roots, or portions of stopping will if carelessly dropped, remain on or at the side of the tongue; and coughing and retching from the presence of saliva or an enlarged uvula will not be liable to occur. In many cases, of course, this position of the head is inadmissible from the surgeon's point of view. Under such circumstances the head should be placed in a line with the body during the administration and lowered just before the operation begins. I find a small air-cushion (which can be deflated at the moment the face-piece is removed) very useful when the position of the head has thus to be changed. When, from the condition of the patient, the A.C.E. mixture or chloroform is considered to be preferable to nitrous oxide or ether, the dorsal posture should be enforced. Such cases are, however, extremely rare.

Mouth-Props.—Before administering an anæsthetic for a dental operation it is customary to insert some form of mouth-prop, in order to avoid delay in separating the jaws when the patient is under the anæsthetic. The plan is a good one for very short operations (20-60 seconds) under nitrous oxide or nitrous oxide and ether. But when a more prolonged anæsthesia (1-10 minutes or longer) is needed, a prop should not be used. Anæsthetics are not taken nearly so well when the mouth is propped widely open as when it is closed, owing to the tongue being forced towards the pharynx, and so favouring difficult breathing. In a very short administration this difficulty will hardly have time to come into play. The mouth-prop used should not be liable to slip; it should be very strong, simple in construction, and capable of being quickly and thoroughly cleansed; and lastly, it should give the operator as much room as possible in the mouth. For several years I have been attempting to devise a prop to fulfil all these requirements; that shown in Fig. 13, p. 201, is in my judgment the best. Corks are liable to slip, as also are most of the ordinary props furnished with soft rubber ends. The former, moreover, may become so compressed during masseteric spasm

that, when the face-piece is removed, the mouth is not sufficiently wide, and delay ensues. The slipping of a prop during the administration of nitrous oxide is a *contretemps* which, though trivial in itself, should be guarded against as much as possible. Should it occur, the best plan, as a rule, is to let the patient come out of the anæsthesia and to readjust the prop more securely; for if time be taken up in opening the mouth of a patient deeply under nitrous oxide, there may not be a sufficiently lengthy anæsthesia for the operation to be painlessly performed. When both sides of the mouth are to be operated upon, an attempt should be made to keep the mouth open with a prop which will allow of the operation being performed without its being removed. Care must be taken, when inserting the Mason's gag, lest teeth be injured, or a mobile jaw dislocated. All mouth-props possessing springs, joints, or other complications should be avoided, not only because of their liability to break or get out of order, but because of the difficulty of keeping them perfectly clean.

Should the patient have **difficulty in opening the mouth,** special care must be exercised (see Illust. Case, No. 37, p. 450). As a general rule the anæsthesia of nitrous oxide is not of sufficient duration to allow of forcibly opening the mouth and of extracting the offending tooth. The teeth should be separated as far as the patient can allow by means of a small prop (Fig. 10, p. 199) which will not slip, and "gas" followed by ether should be given. When the face-piece is removed the mouth may be opened to the desired extent by a Mason's gag. It should be a cardinal rule never to give an anæsthetic to these patients without either inserting a small prop, or, if this be impracticable, without having at hand means for immediately separating the jaws should occasion require. When the teeth can only be separated to a very slight extent, it is an excellent plan to insert a Mason's gag *before* applying the face-piece for "gas" or "gas-and-ether." Care must be taken to exclude air where the pad of the face-piece crosses the arms of the gag. When a sufficient anæsthesia has thus been induced the mouth may be readily opened without loss of time.

Prolonged Dental Operations.—When numerous difficult teeth or roots have to be removed at one sitting, and an anæs-

thesia of some minutes' duration is needed, the anæsthetist may either keep up continuous unconsciousness by means of nitrous oxide, employing one of the methods referred to on p. 242, or he may use this agent merely as a preliminary to deep etherisation. The plan of prolonging nitrous oxide anæsthesia by passing a catheter through the nose is open to obvious objection. The oral tube through which a current of the gas may be transmitted to the back of the throat is liable to get in the way of the operator, and it is practically impossible for the anæsthetist, unless assisted, to simultaneously keep up the gas supply, steady the head, manipulate the gag, and carefully watch the patient. The method of prolonging nitrous oxide anæsthesia by the nose-piece is the best of its kind, but the objection last mentioned applies to it as to other prolongation methods. It is, moreover, impossible to obtain a continuously deep anæsthesia by any of these devices; so that, although ether is undoubtedly open to the objection that its after-effects are often unpleasant, it is certainly far more manageable than nitrous oxide for these operations, and, in addition, allows of steadier and better operating. After a little practice the anæsthetist will find that he can, by regulating the length and degree of etherisation, provide the surgeon with an available anæsthesia of the desired duration, so that no reapplication of the inhaler will be needed. It is a good plan, in these major dental operations, for the operator to first remove the lower and upper teeth of one side; a large sponge is then tightly wedged between the gums of that side; the operation is completed; and the other side of the mouth is similarly plugged. In this way loss of blood may be largely prevented, and if the patient's diet has been carefully regulated as for an ordinary surgical operation (p. 186), after-effects will be reduced to a minimum.

C. OPERATIONS IN THE REGION OF THE NECK NOT INVOLVING THE AIR-PASSAGES

In administering anæsthetics for operations in the region of the neck the following points must be borne in mind:—

(1) Any **embarrassment in respiration** will be quickly

followed by considerable venous turgescence, which may inconvenience the operator. It is hence desirable to avoid all coughing, straining, and hampered respiration, by maintaining a deep anæsthesia.

(2) **Ether** leads to greater vascularity than **chloroform.** But when ether is administered with a sufficient supply of air, and when respiration is regular and unembarrassed, there is very little difference between the effects of the two anæsthetics. The vascularity under ether is far greater in the first ten minutes of the operation than later on.

(3) In some cases considerable **surgical shock** may arise during the operation either from loss of blood or from interference with important vessels and nerves.[1] In addition to Illust. Cases, No. 14, p. 370, No. 49, p. 487, and No. 50, p. 488, I have notes of one other in which considerable circulatory depression took place under ether after the internal jugular vein had been tied, and whilst the internal carotid was being exposed for ligature.

(4) There is a distinct though slight risk of **air entering veins** during these operations (see p. 489). Sternberg[2] has recorded two instances in which gurgling cardiac sounds, due to the presence of air within the heart cavities, were audible after the accident had occurred.

Patients requiring operations upon the **thyroid gland** are not unfrequently the subjects of dyspnœa from tracheal pressure (see p. 125).

Recovery from the effects of the anæsthetic may be more tardy than usual after neck operations, owing to the **tight bandaging** which is often necessary. The anæsthetist should not leave his patient till distinct signs of returning consciousness have been manifested.

[1] Mr. Jacobson (*Operations of Surgery*, 1st edition, p. 451) says, with regard to deep-seated operations in the neck, "Throughout these operations which may necessarily be prolonged and attended with loss of blood, and in which important parts may be disturbed and pulled upon, the surgeon should keep himself informed as to the effects of the anæsthetic." And Mr. Edmund Owen (*Practitioner*, Nov. 1891, p. 324) quotes two cases in which it is probable that the dangerous conditions met with were of reflex (vagal) origin.

[2] *Centrabl. f. Chir.* No. 11, 1899.

D. OPERATIONS INVOLVING THE PLEURA OR LUNG

Patients requiring these operations are, as a rule, suffering at the time from respiratory difficulties more or less pronounced. The reader is therefore referred to the previous chapter (p. 126) for remarks bearing upon the use of anæsthetics in persons thus affected. But although the condition of the patient should primarily occupy our attention, we must also take into account the possibility of circulatory or respiratory difficulties occurring in connection with the operation itself.

The **posture of the patient** in these cases is a matter of importance. Should the lateral position be necessary, the affected or more affected side should, if possible, be lowermost, in order to allow of the free expansion of the healthier lung. Unfortunately, many operations upon the pleura or ribs cannot be performed unless the affected side be uppermost, or the patient be lying almost prone. The prone or semi-prone position is an unsatisfactory one under any circumstances, as it is liable to interfere with respiration; but it is more especially hazardous when a considerable proportion of the trunk-weight is allowed to tell upon the only efficient lung. The administrator should, at all events, *induce* anæsthesia whilst the patient is lying in a favourable position; and then observe whether any effects follow the change of posture. In chronic cases, in which the healthier lung has become enlarged and accustomed to increased work, the posture of the patient is not of nearly so much importance as in more recent cases.

When a **purulent or gangrenous cavity** of the lung or pleura communicates with the bronchi, special attention must be paid to posture; otherwise respiration may become embarrassed by pus, gangrenous matter, or blood obstructing the air-ways (see p. 454).

During the **withdrawal of fluid** from the pleural cavity the circulation of the patient should be watched, and any signs of failure reported to the operator. Syncope is said to have occurred from the sudden return of the heart to its proper position. I have never witnessed any symptoms of this nature.

Operations upon the lung may be attended by **hæmoptysis** during the administration, and it is hence especially desirable, in such operations, to keep the patient upon his affected side, so that the bronchi of the unaffected lung may remain as free as possible for respiratory purposes (see Illust. Case, No. 38, p. 454).

With regard to the **most appropriate anæsthetic**, it is difficult to lay down definite rules. The condition of the patient must be the chief guide. From the point of view of the surgeon chloroform is preferable to ether; but there are many cases in which this latter anæsthetic should be used in preference to chloroform. Whenever possible, ether or an ether mixture should be chosen; for although it may cause some increase in the difficulty of breathing, the circulation will be well maintained (see Illust. Case, No. 8, p. 311). It should, of course, be given by a semi-open inhaler. The greater the respiratory difficulty the lighter should be the anæsthesia.

E. ABDOMINAL OPERATIONS

The successful performance of abdominal operations is not a little dependent upon the skill of the anæsthetist. In the first place, patients requiring these operations are often in a very unsatisfactory condition. Secondly, the operations themselves are amongst the most formidable of modern surgery. Thirdly, unless the level of anæsthesia be properly adjusted, abdominal rigidity, laboured breathing, coughing, "straining," and vomiting will be liable to arise and to seriously embarrass the operator. And lastly, unless care be taken in the selection and use of the anæsthetic, the after-effects may be such as to retard or possibly prevent the recovery of the patient.

In order that the best results may be obtained, attention must be paid to (*a*) the preparation of the patient; (*b*) the selection of the anæsthetic; (*c*) posture; (*d*) the depth of anæsthesia; and (*e*) the factor of surgical shock.

(*a*) **Preparation of Patient.**—Unless special circumstances be present, the diet should be carefully regulated as described on p. 186. When the stomach is distended with fluid, as is often the case in patients suffering from intestinal obstruction,

some surgeons consider it advisable either to wash this organ out before administering the anæsthetic, or to do this when partial anæsthesia has been induced[1] (see p. 174). Special care should be taken to wrap the patient up as warmly as possible. For desperate cases a hot-water bed may with advantage be used. The temperature of the room should be from 65° to 70° Fah., and there should be no draught of cold air. With the object of not keeping their patients an unnecessary length of time under the anæsthetic, many surgeons prepare the skin by washing, antiseptic compresses, etc., before the anæsthetic is given. If the patient be kept anæsthetised for from ten to thirty minutes before the first incision is made, he may pass into a state of false anæsthesia or anæsthetic sleep, the pupils being small, the cornea quite insensitive, the breathing good and quiet, and the abdomen apparently relaxed: and great may be the surprise of the inexperienced anæsthetist when the first incision *immediately* brings back brisk corneal reflex, movement of the legs, deep breathing, and abdominal rigidity (see p. 57).

(*b*) **Selection of Anæsthetics.**—As regards the choice of anæsthetics much difference of opinion exists. One surgeon prefers ether, another chloroform, a third the A.C.E. mixture, and a fourth ether followed by chloroform. The fact is that cases differ so widely in themselves that no generalisation on this point can be definitely adhered to. We may have, at one end of the scale, a perfectly healthy and vigorous subject; at the other an almost moribund patient, with stercoraceous vomiting and a rapid pulse. When the patient's general condition is fairly good the "gas"-ether-chloroform sequence seems to me to fulfil all requirements (see remarks, p. 418). Considerable practice is, however, needed in order to obtain constant and good results by this system. In the absence of such experience the anæsthetist may employ the ether-chloro-

[1] We are indebted to Mr. Greig Smith for some valuable remarks in this connection. (See *Brit. Med. Journ.*, 12th March 1892, for an abstract of Mr. Greig Smith's paper which was read before the Roy. Med. and Chir. Soc. on 8th March 1892, and was entitled "Enterostomy in Intestinal Obstruction.") The writer urges that general anæsthesia should never be induced when the stomach is full of fluid. The stomach should be artificially evacuated; or a local anæsthetic employed. See also *Lancet*, 25th September 1897, p. 786, for other remarks on this subject.

form sequence (p. 417), which, so far as the operation is concerned, is equally efficient, or he may use ether, the A.C.E. mixture, or chloroform throughout. Ether has one great advantage in abdominal surgery: it can be pushed very profoundly so as to abolish all inconvenient reflexes; and when the operation is not likely to be long, and when the patient takes this anæsthetic well, there is no reason whatever against its being given. Ether is often regarded as altogether out of court in this branch of surgery, because of the laboured breathing and inconvenient venous engorgement which it produces; but, when properly administered, ether will produce a condition very similar to that obtainable by chloroform. The A.C.E. mixture is a good anæsthetic for children, for elderly and obese subjects, and for those whose general condition is unsatisfactory. In the earlier days of abdominal surgery, when it was customary to tie down the legs and arms of the patient, and when the surgeon was satisfied with what we now term a light anæsthesia (see p. 18), chloroform or the so-called "bichloride of methylene" seemed to fulfil every requirement. One of the strongest arguments indeed against the view that fatal surgical shock is most liable to arise during a light anæsthesia is, to my mind, to be found in these early abdominal cases. Thousands of patients were successfully operated upon whilst only partially anæsthetised in the present sense of the term; and were it not that this level of anæsthesia is exceedingly inconvenient to the surgeon and his assistants, anæsthetists might still endeavour to maintain their patients in an analgesic rather than an anæsthetic state. We have, however, advanced with the requirements of the surgeon, as will be seen below, and it is now the recognised duty of the anæsthetist to exert all his energies in maintaining as deep an anæsthesia as he considers to be compatible with safety. It will thus be seen why chloroform is not as satisfactory an anæsthetic to-day, in these operations, as it was twenty years ago. In other words, this profound degree of anæsthesia which is essential in the majority of abdominal cases is only to be obtained, with chloroform, by keeping the patient on the very threshold of respiratory and circulatory depression—a feat which may be and is constantly being performed by those

who have had large experience in anæsthetising, but one which can hardly be expected of others. It may therefore be said that, as a routine anæsthetic for use by those of average experience, ether and the A.C.E. mixture are preferable to chloroform in abdominal surgery; whereas chloroform, preferably preceded by "gas-and-ether" as recommended on p. 418, is the anæsthetic for those anæsthetists of larger experience.

(*c*) **Posture.**—There are a few special points to be borne in mind with regard to posture in abdominal operations in addition to those already discussed on p. 138 *et seq.* Trendelenburg's position is now often adopted during surgical procedures of this class, and in my experience answers admirably, a better pulse and colour being present than when the patient is horizontal. The dependent position of the head, moreover, seems to me to be advantageous from the respiratory side, good inspiration being kept up owing to more blood than usual reaching the respiratory centres, and efficient expiration being maintained by reason of the abdominal contents assisting the descent of the diaphragm.[1] I certainly have not found breathing inconveniently hampered, as some have stated; but *it is important that the head should be kept in a line with the body.* The posture in cases of extreme abdominal distension has been already considered (p. 140). The insertion of a sandbag below the lower ribs in operations upon the liver may somewhat impede the action of the diaphragm—a point worth bearing in mind. And lastly, any impairment in breathing (as from flexion of the head upon the sternum, masseteric spasm, etc.) may, by causing violent diaphragmatic action, interfere with the manipulations of the surgeon.

(*d*) **Depth of Anæsthesia.**—Considerable experience is needed in deciding at what depth or level of anæsthesia each patient should be kept. Generally speaking, it may be said that the stronger and more vigorous the subject the deeper should be the anæsthesia, and *vice versa.* Feeble and exhausted patients, those who have been taking opium for the

[1] Descent is here used to indicate the exact reverse of the ordinary descent, for the patient is supposed to be more or less inverted. I have notes of two cases in which abdominal rigidity was less in Trendelenburg's posture than when the patient was horizontal, probably because the abdominal muscles had less to do in expiration.

relief of pain or other causes, and those who have become lethargic as the result of the absorption of poisonous products from the intestinal tract, will be found to require but a small quantity of the anæsthetic to produce the necessary degree of anæsthesia. Such patients may be kept comparatively lightly under the anæsthetic without evincing those inconvenient manifestations which in stronger subjects would certainly arise under similar treatment. But apart from these exceptional cases the anæsthetist should, as a rule, carry the administration to its fullest degree, with the object of avoiding the abdominal rigidity, laboured breathing, coughing, "straining," and vomiting which are so prone to arise unless these precautionary measures be taken. The manipulations of the surgeon within the abdominal cavity are very likely to excite reflex rigidity, "crowing," breathing from reflex laryngeal spasm, and other inconvenient symptoms, even in very deep anæsthesia. Indeed, there seem to be certain cases in which complete abdominal relaxation is only to be secured at the risk of respiratory depression. This is not to be wondered at; for whilst inspiration under anæsthetics is largely diaphragmatic, expiration is often to a great extent dependent upon the contraction of the abdominal parietes. In other words, it is often this expiratory action of the abdominal muscles which the surgeon finds inconvenient. I believe I am right in saying that whilst it is safe in nearly every case to obtain complete abdominal relaxation, it is not safe in all; for I have notes of more than one case in which, wishing to help the surgeon as much as possible, I have carried the administration of chloroform to the point of incipient respiratory failure before I could produce thorough muscular relaxation.[1] In some cases the laryngeal spasm excited by the surgical procedure may become so intense that cyanosis and even arrested

[1] The cases in which I have had most difficulty in this direction have been those in which considerable retraction of the abdomen has taken place in the course of some affection necessitating gastrostomy. The most persistent and board-like rigidity I ever witnessed, however, was in the case of a lady who was very wasted from malignant disease. Oöphorectomy was being performed for recurrent carcinoma of the breast. There was hardly any thoracic respiration (? from secondary lung affection), and although chloroform was given to the fullest degree compatible with safety, the abdominal rigidity persisted and rendered the operation exceedingly difficult.

breathing may result. Curiously enough, there is a greater tendency for events to run this course under chloroform than under ether (see Illust. Case, No. 35, p. 449); so that, should the laryngeal spasm become inconvenient under chloroform, a change to ether may be effected.

(*e*) **Surgical Shock.**—For remarks on this subject the reader is referred to pp. 142 and 481. The symptoms of surgical shock are often so closely interwoven with those produced by toxic quantities of the anæsthetic, or with those dependent upon asphyxia from laryngeal spasm, that they may easily be attributed to wrong causes, and, conversely, the toxic or the asphyxial phenomena may be erroneously referred to surgical shock. In cases of the last-mentioned condition, the pulse invariably begins to improve as the abdomen is being closed.

In administering an anæsthetic for **acute intestinal obstruction** the anæsthetist incurs no small share of responsibility in the case. This has already been pointed out in the preceding chapter (p. 132). Patients with obstruction of the bowels are not good subjects for general anæsthesia. The administrator should make it a rule to keep the patient's head well upon its side throughout; for vomiting comes on very quietly in these cases, and if the anæsthetist be not on the watch he may suddenly find his patient verging on asphyxiation from ejected fluids having entered the larynx. In desperate cases, and especially in those in which the patient is very obese, I generally place a pillow under one shoulder, turn the head well to the opposite side, insert a Mason's gag between the teeth or gums, and have at hand a small sponge for keeping the pharynx clear of fluid. When these precautions are taken, the risk of vomited fluids entering the larynx is reduced to a minimum. Another point worthy of mention is that patients requiring these operations will often be found to be partly under the influence of morphine or opium. The anæsthetist should ascertain this point; and, should an opiate have been given, very little of the anæsthetic will be needed (see remarks on p. 425). Ether often cannot be employed when the abdomen is very greatly distended and the respiration hurried; the best anæsthetic under such circumstances appears to be the A.C.E.

mixture, given upon a Skinner's mask, as described in Illust. Case, No. 31, p. 427. Should ether be preferred, and it may often be advantageously chosen for the more chronic cases, the asphyxial element of the bag inhaler must be used with caution. If the patient be very weak the semi-open method should be employed.

It is usually taught that there is some risk of heart failure during the **evacuation of fluid** from a distended abdomen. I have never seen any symptoms of this nature, although I have watched for them. I should add, however, that as a general rule the patients have at the time either been under ether or a mixture containing ether. In my experience the respiration, and with it the pulse, has always improved during and immediately after the evacuation of fluid (see Illust. Case, No. 17, p. 394).

There is one more point worth mentioning in connection with abdominal surgery. I refer to **flushing out the abdomen** with hot water. This procedure usually improves the respiration, the pulse, and the colour of the patient, whilst it not uncommonly sets up a reflex crowing condition of the breathing. But after the flushing is over, the pulse is apt to flag; and I have known rather disconcerting symptoms to be thus initiated.

F. OPERATIONS UPON THE GENITO-URINARY ORGANS AND RECTUM

In these operations a **profound anæsthesia** is, generally speaking, necessary. This is principally owing to the fact that the genito-urinary organs and rectum are richly supplied with nerves whose sensibility is often exaggerated by the presence of a morbid condition. Moreover, patients suffering from these affections are often highly nervous and peculiarly sensitive, or unhinged by continued pain and sleeplessness. Reflex phenomena, such as loud crowing inspiration, "hesitating" expiration, general muscular rigidity, etc., are therefore more than usually prone to make their appearance. The patient should never be touched by the surgeon till stertor, relaxation, and other signs of a deep narcosis are present.

There is little worthy of special notice concerning operations upon the **external genital organs** beyond what has just been said. It is generally believed that the operation of castration is liable to be attended by grave shock; but although I have watched for this condition in a large number of cases I have never seen it. I have once or twice observed a distinct change of pulse, undoubtedly due to the exposure or removal of the testes, the rate becoming abruptly slower, or some intermission taking place. Such changes are probably more common under chloroform than under ether (see remarks, p. 145).

Patients suffering from **bladder affections** are usually elderly, and are not unfrequently the subjects of obesity, emphysema, and chronic bronchitis; in other words, they are not always the easiest patients to anæsthetise. Distension of the bladder in a patient whose breathing is principally diaphragmatic will at once increase the rate and depth of respiration. I know of no greater problem in the administration of anæsthetics than that of keeping the breathing of an emphysematous patient sufficiently tranquil to meet the requirements of the operator, when the bladder and rectum have been artificially distended preparatory to a supra-pubic operation. It is in such cases as these that ether is quite inadmissible, and the A.C.E. mixture or chloroform becomes necessary.

In operations upon the **kidney** there is often considerable surgical shock, and as a general rule ether is therefore preferable to chloroform. The shock is likely to be greater in feeble than in moderately healthy persons (see Illust. Cases, No. 44, p. 484, and No. 45, p. 484).

A few words may be said concerning the use of anæsthetics in **rectal surgery**. Full-blooded, well-nourished patients and those in average health pass through these operations without giving any anxiety to the anæsthetist, always provided that ether be employed, and the deepest anæsthesia maintained. But there is a certain type of patient, with whom every surgeon who has had much experience in this department must be familiar, who requires careful handling. He is rather pale from occasional loss of blood, of spare build, and from having been greatly overworked and overtaxed in his profession or business, and worried by his rectal disorder, he has become

nervous, and altogether unhinged. Such a patient may show signs of feeble circulation during or after the use of the anæsthetic. The symptoms are probably reflex in character (see p. 143). There is always some degree of surgical shock in excision of the rectum and in Kraske's operation. In the latter procedure, moreover, the anæsthetist must guard against intercurrent asphyxia due to the prone posture. In adjusting the patient for this operation the head should be brought to the side of the table, and it is sometimes possible, by arranging small pillows under the shoulders or spines of the pelvis, to provide against undue respiratory embarrassment. In obese and other bad subjects for this operation the hampered breathing may be quickly followed by circulatory depression.

G. OPERATIONS UPON THE BREAST

There is a greater liability to surgical shock during breast operations than is generally believed, and the anæsthetist should therefore do all in his power to aid the surgeon in preventing and treating this condition. Signs of circulatory depression may appear as the immediate result of the skin incision, as a sequel to hæmorrhage, or as the consequence of the exposure and manipulation of a large raw surface. The patients most liable to surgical shock are those whose general condition is unsatisfactory; and the operations most likely to induce this condition are those in which a large surface is exposed and a good deal of blood lost. The symptoms are most likely to come on at that part of the operation which immediately precedes the actual removal of the breast, and the state of the patient almost invariably begins to improve immediately the removal has taken place. The etiology, management, and treatment of surgical shock are fully considered in other parts of this work (see pp. 142 and 481).

With regard to the best anæsthetic, this must be decided by a careful consideration of the patient's general state of health. The "gas"-ether-chloroform or ether-chloroform sequence answers well in most cases. For patients over sixty-five years of age, and for very obese subjects, the C.E. or A.C.E.

mixture gives the best results. Ether answers well for short operations upon young and middle-aged patients whose general condition is satisfactory. One advantage of this anæsthetic over chloroform in mammary surgery is that there is little or no liability, after its administration, for secondary hæmorrhage to occur. It is not a very uncommon event for a good deal of oozing to take place, or for active hæmorrhage to arise, in cases in which chloroform has been used throughout. The anæsthetist should see that the patient's body is not more exposed than is absolutely necessary, and the room should be kept as warm as for an abdominal section.

H. OPERATIONS INVOLVING THE BRAIN OR SPINAL CORD

Patients about to be subjected to these operations are sometimes more or less **drowsy or comatose** at the time of administration; and the anæsthetist should therefore carefully ascertain the exact condition of the patient before giving the anæsthetic (see p. 133). So far as the actual performance of the operation is concerned, the best results appear to have been obtained by the use of **chloroform.** The mixed narcosis of chloroform and morphine, which was for some time employed in these cases, is now rarely used (see Chap. XV.). Should a preliminary injection of morphine have been given, the anæsthetist must administer chloroform in small quantities at a time, and attempt to secure an analgesic rather than a true anæsthetic state. Should no morphine have been administered, deep anæsthesia will, at all events at first, be necessary. When intracranial pressure is abnormally high, respiration may cease during the induction of anæsthesia, and it may be necessary to relieve the tension before breathing can be re-established.[1]

The chief point concerning operations upon the spinal column and cord is that the prone or almost prone posture may introduce asphyxial complications. In some cases, moreover, there may be no thoracic breathing; and the thoracic

[1] See a case reported by Dr. Percy Noble (*Lancet*, 28th April 1900, p. 1210).

viscera may be much interfered with by the spinal deformity. Generally speaking, very deep anæsthesia should be avoided in the prone posture, and a careful watch kept upon respiration and circulation. The choice of the anæsthetic must be regulated by the general circumstances of the case. Although chloroform may be preferable from the surgeon's point of view, the anæsthetist may find it advisable in bad cases to employ ether, either alone or in mixture with chloroform. Operations for spina bifida in infants are best performed under ether (see footnote, p. 116).

I. PARTURITION AND OBSTETRIC OPERATIONS

Of all the anæsthetics at present known, chloroform is the most suitable for administration during **natural labour.** It quickly produces an **analgesic** state without materially affecting uterine contractions. The patient passes into a dreamy condition, with rather deep respiration, and a pleasant feeling of numbness in the extremities. Speaking generally, chloroform should not be pushed beyond this point. It is not desirable to commence the administration until there is distinct evidence that true labour pains have begun. When the patient shows by her movements that a "pain" is approaching, chloroform should be applied; as little as possible given; and even before the "pain" has actually passed off the anæsthetic should be withdrawn. The patient should be allowed to recover completely from the analgesic effects of the drug between the "pains"; and in these periods food or stimulants may be taken. During the expulsion of the fœtus, Spiegelberg[1] recommends that consciousness should be allowed to return in order to lessen the risk of the perineum becoming ruptured. Most obstetricians agree that if chloroform be given more deeply than is here suggested there is a risk not only of uterine inertia, and a prolongation of the labour ensuing, but of *post-partum* hæmorrhage, more especially in persons predisposed to this condition. **Chloroform should not be employed** when the uterine contractions are

[1] *A Text-Book of Midwifery* (New Syd. Soc.), vol. i. p. 268.

feeble, when small doses of the drug appear to retard labour,[1] or when any great respiratory difficulty is present.

When **true surgical anæsthesia** is required, as for turning, instrumental delivery, craniotomy, and other operations, ether should, as a general rule, be given. Though the use of chloroform in analgesic doses during labour may be said to be free from risk, there is no reason to suppose that when this anæsthetic is pushed to its fullest degree this almost absolute immunity from danger is to be relied upon.[2] But seeing that chloroform has been very largely used for obstetric operations requiring deep anæsthesia, and that very few fatalities have occurred, it would seem that there must be some explanation of this freedom from accident. When fatalities under chloroform have occurred in surgical practice at the very outset of the inhalation, *i.e.* before consciousness has been lost, the elements of fright and apprehension have possibly been at work. These elements are, as a rule, wholly absent when chloroform is given to relieve the pains of labour. The patient is occupied with her suffering, and the prospect of speedy relief from pain gives rise to a feeling of comfort rather than to one of alarm. The view that the physiological hypertrophy of the heart enables this organ to cope with any undue strain which may be imposed upon it is probably quite erroneous. A very large proportion of those who have succumbed under chloroform have had healthy and vigorous hearts. Moreover, the clinical fact is established beyond doubt that, in surgical practice, the best subjects for chloroform are those whose general vital functions are somewhat impaired by illness. In the comparatively few cases in which I have myself administered chloroform to its full extent during or immediately after labour, the patients have certainly taken this anæsthetic remarkably well. There has seemed to be a fuller and better circulation and respiration than in ordinary

[1] For further information I would refer the reader to Dr. Galabin's practical remarks. See *A Manual of Midwifery*, 2nd edition.

[2] It is a mistake to suppose that chloroform accidents during child-birth are unknown. See a fatal case, *Lancet*, 2nd Feb. 1889, p. 249. The administrator had given chloroform four hundred times before. See also an article by Dr. Ballantyne (*Scot. Med. and Surg. Journ.*, Jan. 1897). The author has collected eight deaths during labour under chloroform.

cases. Dr. Lombe Atthill,[1] who has had forty years' experience with chloroform in obstetric practice, suggests the possibility of the safety being due to the fact that "in these cases the involuntary expulsive efforts seldom entirely cease, and as at the expiration of each of these, comparatively deep inspiration follows, it may tend to prevent asphyxia. . . ." Mr. A. H. Tubby[2] very aptly harmonises Dr. Atthill's clinical facts with recent physiological teaching; and his remarks are very interesting. There can be no doubt that in many cases in which chloroform produces unsatisfactory effects, the difficulty seems to be one arising in the first instance from feeble or hampered respiratory movements, and consequently an inadequate pulmonary circulation. The deep respirations of labour would obviate this sluggish pulmonary circulation by emptying the right heart more efficiently. Dr. Galabin believes that the high abdominal pressure which is necessarily caused by the distension of pregnancy prevents that undue vaso-motor dilatation which might otherwise arise under chloroform.[3]

J. OPHTHALMIC OPERATIONS

There are special reasons why the maintenance of a perfectly tranquil anæsthesia during ophthalmic operations is a matter of comparative difficulty. In the first place, the head is usually adjusted face upwards and slightly extended; so that mucus and saliva tend to flow backwards and to induce reflex disturbances, whilst the tongue may obstruct breathing. Secondly, the depth of anæsthesia is liable to considerable fluctuations, by reason of the anæsthetist having to discontinue the administration from time to time, in order to meet the requirements of the surgeon. And thirdly, the eyes are often unavailable as guides. There have been a large number of chloroform fatalities in ophthalmic practice, and the explanation of the fact is, I think, to be found in these considerations.

[1] *Brit. Med. Journ.*, 16th Jan. 1892.

[2] *Ibid.*, 30th Jan. 1892.

[3] For further information see an interesting *résumé* of the whole subject by Mr. H. Bellamy Gardner (*Brit. Gynæcolog. Journ.*, May 1896). The author points out that there is no decided evidence to show that anæsthesia has any injurious influence on the fœtus.

Ether is, in one sense, a more suitable anæsthetic than chloroform, because the patient can be placed so deeply under its influence that inconvenient coughing, swallowing, straining, or vomiting may be prevented. The anæsthetic, whatever it may be, must be pushed freely. There are, of course, many cases in which, from the patient's age or general condition, the A.C.E. mixture or chloroform should be used, either in preference to ether or in succession to that anæsthetic. Thus, for iridectomy in elderly people, the A.C.E. mixture answers admirably. For strabismus operations in children, ether is unquestionably preferable to chloroform.[1] For the operation of enucleation the choice of the anæsthetic must depend upon the state of the patient.

K. OPERATIONS UPON THE EXTREMITIES

Very complete **muscular flaccidity** is essential for the examination of stiff and painful joints, the reduction of dislocations, and the setting of fractures. Ether certainly seems specially called for in reducing dislocations of the shoulder, for chloroform has, curiously enough, proved particularly lethal during these operations.[2]

For orthopædic operations deep anæsthesia is also essential. The legs and feet are particularly liable to reflex movement, even when the anæsthetic has been freely pushed. This is noticeably so in the case of nitrous oxide. Even if this

[1] Mr. Brudenell Carter, in a very able letter to the *Lancet* (7th August 1875, p. 227), strongly advocates the use of ether in preference to chloroform in ophthalmic practice, and refers to a surgeon who lost sixteen patients under chloroform administered for operations upon the eye.

[2] Lisfranc, Verneuil, Böckel, and Guillon have all drawn attention to this fact. They believe the fatalities to have arisen in consequence of the "unfavourable position of the patient" during the administration, by which I suppose they mean that respiration is likely to be interfered with during the necessary manipulations. We must remember, too, that complete relaxation is always essential, in other words, that the anæsthetic has to be pushed very freely; that the subjects of dislocated shoulder are often men who have met with the accident whilst under the influence of alcohol; that food is likely to be present in the stomach when anæsthesia is induced; and lastly, that the administration is not unfrequently left in unskilled hands. These facts, together with the suggestion made by the above observers, seem to me to point to the necessity for considerable caution in administering chloroform for the reduction of a dislocated shoulder.

anæsthetic be administered with oxygen till as deep an anæsthesia as possible is procured, there is almost invariably a reflex twitch when an incision about the leg or foot is made. The best plan of anæsthetising small children for short orthopædic operations is to fit a bag containing half a gallon of nitrous oxide to a charged Clover's inhaler (see p. 407); to allow the patient to breathe the gas backwards and forwards from the beginning; to gradually turn the ether indicator to "1" or "2"; and to admit a breath of air occasionally. Respiration becomes deep, there is no "jactitation," and the muscles quickly relax. The incision is now made. An administration of three minutes suffices for an operation of from one to two minutes, the inhaler being finally removed just before the operation is really completed. This plan avoids the "jactitation" and reflex movement so common with nitrous oxide alone. In adults, and especially in women, better results may be obtained with nitrous oxide. Indeed, when this gas is administered with oxygen, most women may be successfully anæsthetised for operations upon the extremities. Vigorous young men are liable to exhibit reflex movement, but elderly men are again good subjects.

L. OTHER OPERATIONS, PROCEDURES, OR CONDITIONS FOR WHICH ANÆSTHETICS MAY BE REQUIRED

There is nothing worthy of special remark concerning the use of anæsthetics during **other surgical operations and procedures.** A few words may, however, be said with regard to the induction of partial or complete anæsthesia for the relief of certain painful, spasmodic, or convulsive conditions.

General anæsthetics, and more particularly chloroform, are sometimes employed in **renal colic, biliary colic,** and **other acutely painful seizures.** In such cases the selected agent should be administered in analgesic rather than in anæsthetic doses, and, as when exhibiting chloroform in normal labour (p. 179), pain should be relieved without wholly destroying consciousness.

Chloroform has been very extensively used in the treatment

of **puerperal eclampsia.** In these cases it is necessary to push the administration somewhat more freely than when the mere relief of pain is desired. Dr. Galabin[1] makes the following practical remarks: "At first the patient may be brought pretty fully under the influence of the drug, but afterwards it may be given only from time to time, and in partial degree. Any premonitory signs of a paroxysm, such as increased muscular restlessness, more rapid breathing, or contraction of the pupils, are indications for giving more of the chloroform, and so, *a fortiori*, is the recurrence of a fit. When chloroform is given judiciously, in this partial degree, the administration may be continued for hours together, without danger." Dr. Playfair[2] points out that chloroform occasionally fails to control the paroxysms. The same author states that the use of an anæsthetic is contra-indicated when the patient is cyanosed. Spiegelberg[3] refers to a case in which sudden death took place during the use of chloroform for puerperal eclampsia.

Chloroform quickly relieves the spasms of **strychnine poisoning.** In some of the recorded cases it was only necessary to give the drug in analgesic doses;[4] whilst in others deep anæsthesia was produced.[5] In one case[6] chloroform was administered, almost without intermission, for seven hours.

In the treatment of **tetanus**, chloroform has also been found distinctly advantageous.[7] As in strychnine poisoning, muscular spasm subsides before true anæsthesia is reached; so that it is not necessary to push the chloroform very far. Sometimes a considerable interval of freedom from spasm may elapse after the inhalation, in which case no more of the anæsthetic need be given till the tetanic rigidity recommences. But should the spasms be nearly continuous the administration may be maintained. One case is recorded in which a child was kept more or less under the influence of chloroform for thirteen consecutive

[1] *A Manual of Midwifery*, 2nd edition, p. 324.
[2] *Science and Practice of Midwifery*, vol. ii. 6th edition.
[3] *A Text-Book of Midwifery* (Sydenham Society), p. 220.
[4] *Brit. Med. Journ.*, 22nd April 1882, p. 575.
[5] *Lancet*, vol. ii., 1875, p. 310.
[6] *Ibid.* vol. ii., 1867, p. 118.
[7] See *Braithwaite's Retrospect*, vol. ii., 1877, p. 59—"On the State of Therapeutics in Tetanus." See also *Medical Record*, 15th June 1879, p. 243; and *Lancet*, 31st July 1880, p. 171.

days, 100 oz. being used. In extreme cases, in which there is intense spasm of the jaws, neck, thorax, and abdomen, it may be difficult or impossible to administer chloroform without intensifying the existing condition.[1]

[1] A case occurred at the London Hospital in March 1899, in which several attempts were made to relax the tetanic spasm which was threatening the life of the patient by asphyxia. On each occasion the chloroform vapour, even though very carefully given, seemed to aggravate the condition, and artificial respiration became necessary in re-establishing breathing. Eventually, however, the tetanic spasm got the upper hand, and the patient died.

CHAPTER VIII

THE CIRCUMSTANCES OF THE ADMINISTRATION

In order to ensure, as far as possible, a successful administration, it is essential that attention should be paid to numerous details.

It is always advisable to have a third person in the room during the administration of an anæsthetic.

A. HOUR OF ADMINISTRATION: REGULATION OF DIET

Speaking generally, anæsthetics should be administered at or about the time that patients are in the habit of taking a meal; and it is advisable, in regulating the diet before an operation, that the usual hours for food should be interfered with as little as possible.

It is generally agreed that the **early morning (8 a.m.–9 a.m.)** is the best time for the administration of a general anæsthetic for a surgical operation. Putting exceptional cases aside, patients are brighter and fresher in the morning than in the after-part of the day. But the most important reason for choosing the time indicated is that in most cases the stomach is then empty. Adult patients in good health may be allowed their usual meals the day before the operation, provided nothing be taken after 7 or 8 P.M., and that no excess either in food or drink be indulged in. A light and nutritious meal at or about 7 o'clock on the previous evening is generally to be recommended. I have known patients who have had an exceptionally good dinner the night before the operation, and children who have eaten heartily of pudding before going to

bed, to eject a considerable quantity of semi-digested food after the anæsthetic on the following morning, even though nothing whatever had been taken during the night. The practice of giving a cup of tea or coffee, a glass of milk, an egg beaten up in milk, an egg with brandy, or in fact anything whatever, at 6 A.M. or 7 A.M. (*i.e.* two hours or so before an early operation), is open to much objection. Digestion is not always as rapidly performed as is generally believed, and when nourishment is taken at unusual times, the process may be greatly retarded. Mental disturbance, too, is said to interfere with the digestive functions.

The next best time for operations is probably **1.30 or 2 p.m.**, *i.e.* about the patient's usual luncheon or dinner hour. If this time be chosen, tea or coffee with toast may be taken at 8 A.M., and nothing whatever after.

Should the operation be fixed to take place at some other time than those above indicated, special care should be taken to keep the stomach as empty as possible; for when the operation is arranged for **11 or 12 o'clock in the morning**, or for **3, 4, or 5 in the afternoon,** persons are liable, unless specially warned, to have had their breakfasts or mid-day meals as usual. It is better to err, if at all, on the side of abstinence. Young adults in good health should, for example, be allowed to remain without food for from five to six hours. This can be done by arranging a light breakfast at 8.30 or so, and the operation for 3 P.M. Should the operation be arranged for 11 or 12 in the morning—an hour open to objections—the best plan perhaps is for the patient to have a cup of tea, coffee, or cocoa and dry toast at about 6-7 A.M.

The above rules can hardly be adhered to when we have to deal with **exhausted patients**, or with those who are liable to feel faint after a comparatively short abstinence from food or stimulants. Moreover, patients advanced in years should not be kept quite so long without food as younger persons; partly because they more readily show signs of exhaustion, and partly because they are less liable than their juniors to after-nausea and vomiting. Generally speaking, exhausted and asthenic subjects who are to be operated upon in the early morning should be allowed some clear soup during the night;

and in extreme cases a little wine, brandy, or whisky may at the same time be taken with advantage. Similar arrangements are indicated when the operation is fixed to take place during the day, *i.e.* some soup should be given about three or four hours before the administration. Milk, eggs, and ordinary beef tea are not so suitable as clear soup.

As a general rule **alcohol** should not be given by the mouth before an anæsthetic, as it is very liable to interfere with anæsthesia.[1] There are some,[2] however, who adopt this practice and speak well of it.

Should the patient's **circulation** be **extremely feeble**, it is a good plan to give an enema of brandy and water, or brandy and beef tea, a short time (twenty minutes or so) before the administration.

Although it is unnecessary in the case of nitrous oxide that the diet should be as strictly regulated as in the case of ether or chloroform, it is important that some attention should be paid to this point. When the gas is administered in its pure state, an interval of from 2 to 3 hours after the last meal is advisable, although it is exceedingly common for patients who have quite recently taken food to pass through this form of anæsthesia without vomiting. But when nitrous oxide is to be given with oxygen, even for brief operations, the diet must be carefully regulated, in accordance with the foregoing principles. And the same may be said when one administration of pure nitrous oxide is to be immediately followed by another, or when this gas is to be given with air for a lengthy operation.

B. STATE OF THE BOWELS AND BLADDER

In ordinary surgical cases, the best plan appears to be to give a purgative the night but one before the operation, and an enema on the morning of the operation. If a purgative be given the night before the operation, inconvenience may arise

[1] In one case, in which a patient had taken some champagne two hours before I gave him nitrous oxide and ether for a dental operation, hesitating breathing, masseteric spasm, coarse moist laryngeal sounds, and other inconvenient symptoms arose, and caused delay and difficulty.

[2] See Clover, *Brit. Med. Journ.*, 14th February 1874. See also an interesting letter "On the Value of Alcohol before Chloroform" (*Brit. Med. Journ.*, 20th July 1889). Also *Asclepiad*, January 1892.

during, or immediately after, the administration. Care should be taken to select purgatives appropriate to the case. I have on one or two occasions satisfied myself that certain symptoms of depression[1] which have arisen, during or after the use of an anæsthetic, have been wholly or partly dependent upon the violent purgation to which a somewhat feeble patient has been subjected. There are, of course, certain cases in which the use of strong measures is highly desirable. The so-called "bilious" subjects, those who are generally constipated, and young people (particularly boys) of gluttonous habits, must be freely purged, otherwise after-vomiting will be likely to be troublesome.

The bladder should invariably be emptied before anæsthesia is induced. This rule is particularly necessary in the case of children who are about to be anæsthetised by nitrous oxide free from oxygen, for during the clonic muscular movements micturition is liable to arise.

C. CERTAIN SPECIAL PREPARATIONS

Special preparations are occasionally adopted before administering a general anæsthetic. For example, in such operations as those for fæcal fistula, it may be necessary to employ **rectal feeding** for one or two days beforehand. Some surgeons **wash out the stomach** prior to abdominal section for intestinal obstruction (p. 170). In cases of extreme exhaustion, nutrient and stimulant enemata, the subcutaneous use of **strychnine**, or even the **intravenous injection** of saline fluid may be indicated. The employment of **morphine** in association with general anæsthetics is specially dealt with in Chapter XV. Lastly, the preliminary application of **cocaine**, in the form of spray, to the nose and throat, has been recommended, partly with the object of preventing or lessening the cough, holding of breath, and irritation often produced by ether and chloroform, and partly with the object of averting the early reflex syncope which such irritation is supposed to occasionally

[1] Snow believed that free purgation the night before a rectal operation would be likely to induce syncope during anæsthesia; and he met with cases which appeared to render this view extremely probable. See Snow, *op. cit.* p. 104.

induce (p. 91). Rosenberg[1] originally proposed this method: and it has been thoroughly tested by Gerster,[2] Mayer, and Theobald of New York. Whilst there can be no doubt that the irritant effects of anæsthetic vapours may be to a great extent averted by this means, experience has shown that it is not without its objections, and that symptoms of cocaine poisoning may readily be induced. Moreover, as we shall subsequently see, it is highly doubtful whether chloroform vapour is capable of producing fatal reflex syncope by its local action (p. 346).

D. INSPECTION AND EXAMINATION OF THE PATIENT

Bearing in mind the fact that the phenomena of surgical anæsthesia are largely dependent upon age, temperament, physique, habits of life, quantity and quality of blood, state of the respiration, state of the circulation, and other factors (Chap. VI.), we cannot fail to recognise the advantages of ascertaining, as far as circumstances will permit, the general condition of the patient entrusted to our care. In the majority of cases a brief inspection is all that is needed. The more practice the anæsthetist has had, the less need will there be for any systematic examination. It is better, however, to err on the side of an unnecessarily cautious investigation, than to overlook symptoms which, if recognised, would be of service in conducting the administration. When any doubt exists, therefore, as to the state of the patient's health, it is a good plan to employ the stethoscope, or to adopt any other means that may suggest themselves for ascertaining the presence of any important morbid condition. It is a mistake to suppose that a prejudicial state of alarm is brought about by the few simple procedures and questions which are advisable on these occasions. A patient who is in a good state of health is usually fully aware of the fact, and is not likely to feel distressed whilst his heart is being auscultated, and his chest expansion tested. Apprehension is more often caused by the manner in which these inquiries are conducted than by the inquiries themselves. Nervous persons

[1] See *Berliner klinische Wochenschrift*, Nos. 1 and 2, 1895.
[2] See *Annals of Surgery*, Jan. 1896.

are just as likely to gain comfort and confidence by their state of health being properly gauged, as to suffer from increased dread and alarm. But, even admitting that an examination of the patient is open to objection on the grounds indicated, we are surely not justified in allowing any such objections to carry weight. Every one who has largely administered anæsthetics must be able to call to mind cases which would certainly have gone more smoothly had some particular pre-existing peculiarity or morbid state been recognised before the administration. Aortic disease, mitral stenosis, an extremely slow cardiac action, or emphysema may, for example, be easily overlooked unless care be taken. It is certainly erroneous to argue that as the patient *must* have an anæsthetic there is no need to ascertain his fitness for it. By carefully taking into consideration the condition of the patient, we not only place ourselves in a better position to decide what anæsthetic or anæsthetic mixture should be chosen, but we are often able to anticipate the occurrence of important symptoms during the administration. When circumstances permit, therefore, it is a good plan for the administrator to make himself acquainted with the patient's general state.

A great deal of valuable information, both positive and negative, is afforded by the **general appearance and bearing of the patient.** Let us in a few words consider what may be learnt by simply observing the individual before us. Should he walk to the operating table, couch, or chair, his mode of progression may afford us information. We shall notice whether he moves actively, or whether with considerable hesitation or difficulty. Should the exertion be followed by breathlessness we ought specially to bear the fact in mind. Should the patient be partially or wholly recumbent when we are called upon to anæsthetise him, we should note what position is assumed from choice. We should more particularly pay attention to the number of pillows the patient requires. Those who suffer from chronic bronchitis, emphysema, other affections of the air-passages, or extreme abdominal distension, almost invariably insist upon being propped up to a greater or less degree. Marked orthopnœa will attract attention, and should be regarded as a very unfavourable symptom. Patients

suffering from unilateral pulmonary or pleural affections will probably be found lying upon the diseased side. Whilst observing and drawing our inferences from the walk or posture of the patient, we are able, as a rule, to roughly estimate his age. It must be remembered that the anæsthetist is concerned as much with the apparent as with the real age of his patient. The temperament, too, which plays an important part in determining the manner in which an anæsthetic is taken, usually quickly shows itself on these occasions. This is more particularly the case with hysteria. It must be remembered, however, that women who are liable to outbursts of hysteria sometimes conceal their want of control so efficiently that the observer is deceived. The overworked and the highly-strung patient will be recognised, and should be treated with the utmost gentleness and care. Previous excesses in alcohol, as a rule, present little or no difficulty in their detection. The general physique of the patient will be observed. Gross, flabby individuals, with a large abdomen, muddy complexion, and double chin, will probably not be easy subjects to manage. Florid, muscular young men, who live an outdoor life and enjoy excellent health, are also liable to give the administrator some difficulty. Persons afflicted with extreme obesity may also be regarded as bad subjects for certain anæsthetics. Conversely, patients of slim build, and more or less anæmic in appearance, do particularly well during general anæsthesia. The colour of the patient's face and lips should be noted. A florid rosy tint denotes, as a rule, a good state of health and the absence of nervousness or respiratory derangement. The hectic flush, however, must not be allowed to deceive. Florid and more especially dusky-looking and congested patients will be very liable to show cyanosis under nitrous oxide or ether—in fact under any anæsthetic, if air be withheld even to a slight degree. The pallor of true anæmia is readily recognised. Apart, however, from this pallor, we must remember that very nervous and apprehensive subjects are prone to be much paler than usual at the time of administration; their pallor disappears when anæsthesia is established; and, often to the surprise of the anæsthetist, to whom the patient may be a stranger, a good florid colour will persist throughout the administration. The

anæsthetist should take special note of the **manner in which respiration is performed**, and if any marked abnormality in this direction be detected a further examination of the patient should be made. If there be no obvious shortness of breath or distress in breathing, and if the respiratory movements are quiet and the colour of the lips good, there is, as a rule, no need for any further examination. It is usually a good plan, however, to ask the patient to take a deep breath. In this way the administrator will see whether the chest expands freely, and whether the respiration is principally thoracic or abdominal. By getting the patient to take a deep breath the administrator may hear if there is any sound suggestive of narrowing of the air-way, bronchial catarrh, emphysema, etc. A loose, frequent, or hollow cough should not escape attention. The cough of simple nervousness is easily distinguishable. The **pulse** should invariably be felt; and as a general rule it is a good plan to **apply the ear or stethoscope to the chest.** Any duskiness, pallor, or breathlessness should suggest a stethoscopic examination. Feebleness, irregularity, intermittency, or marked slowness of pulse should lead to further inquiry.

The **oral cavity should be inspected** by the anæsthetist. **Artificial teeth**, even though firmly fixed and apparently safe, should always be removed. It is important that, at the time of administration, there should be nothing within the mouth which is loose or likely to become loose. On one occasion during the administration of ether I discovered a tooth lying loose in the mouth. My attention was directed to it by finding a little blood issuing from the lips. During the closure of the jaws a shaky tooth had apparently become dislodged. It is hence best to see that no such teeth are present, or if present to take special care lest they become detached. I once also found, loose in the mouth, a portion of tartar about the size of a large pea, which must have been left attached to the gum when the patient removed two artificial teeth before the administration. A "quid" of tobacco has been known to lead to asphyxial symptoms during anæsthesia. In the case of children, sweetmeats may possibly be present in the mouth at the time of administration. Should the patient be the subject of partial or complete **nasal obstruction**, the anæs-

thetist must take note of the fact, as the condition is liable to give rise to some difficulty during the administration.

E. ATMOSPHERIC CONDITIONS: TEMPERATURE OF ROOM: CLOTHING: MAINTENANCE OF BODILY HEAT

As already pointed out (p. 42), the absorption of vapours and gases by the blood is directly influenced by **barometric pressure.** But putting aside such exceptional cases as those in which the pressure is artificially raised (as in Bert's method of administering nitrous oxide and oxygen already referred to), and those in which it is naturally lowered (as it would be in administering anæsthetics at high altitudes), the fluctuations in barometric pressure which are constantly taking place have little, if any, influence upon the phenomena of anæsthesia. Further research, however, upon this point is needed before any very positive statements can be made.

The **temperature of the air** during the administration of volatile anæsthetics is of considerable importance, a comparatively high temperature being favourable to vaporisation (see p. 42), and to subsequent elimination, a low temperature having an opposite influence. Whenever practicable, the room in which the administration is conducted should be from 65° to 70° Fah., according to the nature of the operation; it should be ventilated but free from draughts; it should have a fireplace; and, unless the weather be very warm, a fire should be burning.

When the temperature is very low, delay and difficulty in anæsthetisation may be anticipated.[1] Again, according to the late Sir B. W. Richardson,[2] a very moist atmosphere may also interfere with absorption and elimination, whatever the temperature may be. This observer believed that when the air was surcharged with aqueous vapour, syncopal attacks under chloroform were particularly prone to be fatal, and that pul-

[1] In the *Dental Cosmos* of 1869, p. 659, a case is related in which chloroform anæsthesia could not be induced when the temperature of the room was at 45° Fah., whereas, on a subsequent occasion, when the temperature was 70° Fah., the same patient was successfully anæsthetised. I have myself met with a somewhat similar case.

[2] *Asclepiad*, 1892.

monary œdema was more likely to result than if the air were dry.

Patients certainly seem to take anæsthetics better when the weather is warm, dry, and bright than when opposite conditions prevail; but we must not forget that catarrhal affections of the nasal, pharyngeal, and laryngeal channels are much more common in cold damp weather, and that these affections, even though slight, may readily introduce difficulties into an administration. The special disadvantages of administering chloroform in small rooms heated or lighted by gas or oil lamps have already been considered.

Patients who are about to inhale an anæsthetic, whatever that anæsthetic may be, should invariably be **loosely but warmly attired.** In the case of nitrous oxide, persons are liable to think they are being put to unnecessary inconvenience by being obliged to unfasten corsets, belts, collars, etc., but nothing should be permitted to stand in the way of such precautions being adopted. It does not follow that because a patient with a tightly-laced waist can take a full breath she will be able to breathe freely under nitrous oxide; indeed, the reverse is likely to be the case. Anything that constricts the waist or prevents free thoracic or abdominal movement should be loosened. The front of the dress, or the coat, as the case may be, should be unfastened. Collars, too, should be unbuttoned or removed. Not only may the collar be uncomfortable to the patient if his head should be thrown backwards, but it may interfere with the upward or downward movements of the larynx which usually occur during deep respiration. Corsets should always be unfastened. All these precautions are not only necessary because of their providing for free respiration, but they are desirable, because, should any unexpected respiratory embarrassment occur during anæsthesia, remedial measures can far more efficiently be carried out than when the patient is attired in constricting clothing.

The **maintenance of bodily heat** is of great importance in all cases requiring a more or less protracted anæsthesia. Under ether and chloroform the temperature invariably falls, sometimes to a considerable extent, and it is the duty of the anæsthetist to do his best to counteract this fall. Patients

1. Instruments for opening the mouth and maintaining it in that position.
2. A pair of tongue-forceps.
3. A small basin, a towel, and a small piece of sponge.
4. Instruments for performing tracheotomy.

The anæsthetist should always be prepared to open the mouth of the patient without delay. There are some forms of respiratory embarrassment which can only thus be relieved.

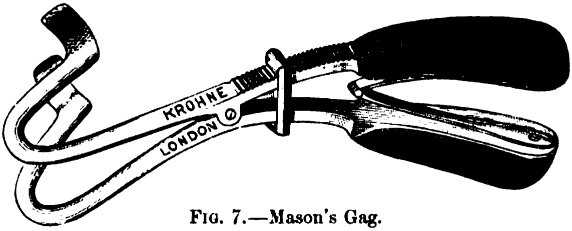


FIG. 7.—Mason's Gag.

When the teeth are more or less deficient, all that is necessary is to introduce a **Mason's gag**. The gag shown in Fig. 7 is, in my experience, the best. The spring should be strong, so that the blades come closely together, and the notches for the movable catch should not be too deeply cut. The parts of the gag which come in contact with the teeth or gums should be covered with rubber tubing. Should there be any difficulty in introducing this gag, which is not unfrequently the case in

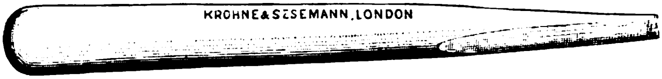


FIG. 8.—Wooden Wedge for separating clenched teeth.

muscular subjects with good teeth, some form of **mouth-opener** should be used. The wooden wedge of Fig. 8 answers well; or the whistle-shaped brass wedge of Fig. 9 may be employed.[1] A small strong **mouth-prop**, so made that it cannot slip when placed between the front teeth (Fig. 10), is often of use either for inserting before commencing the administration or for introducing subsequently should it be found advisable to keep the teeth apart.

With regard to **tongue-forceps**, those shown in Fig. 11 are

[1] See *Brit. Med. Journ.*, 15th Jan. 1898.

as efficient as any. Some administrators, following the recommendation of Lord Lister, use a simple pair of artery forceps,

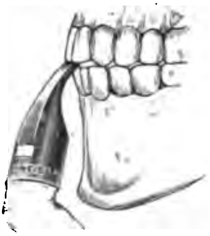


FIG. 9.—The author's Mouth-opener.

FIG. 10.—Mouth-prop for keeping the teeth apart during the administration (actual size).

which certainly have the merit of not being liable to slip when once they have taken hold of the tongue.

It is a good plan to fix a moist **piece of sponge** of appropriate size between the blades of the tongue-forceps, so that

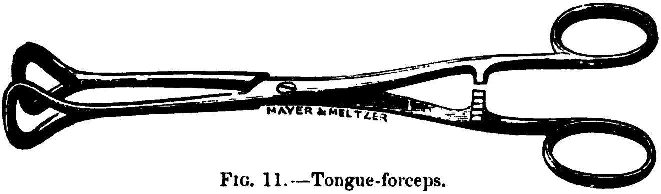


FIG. 11.—Tongue-forceps.

the mouth may be sponged out if necessary. This is particularly important in cases of intestinal obstruction attended by vomiting.

A **small basin** should be at hand in case of vomiting, the non-occurrence of which cannot be prophesied with certainty in any instance.

In ordinary surgical practice a **towel** will be found useful for wiping out the corners of the mouth, for rubbing the lips and cheeks (p. 361), or for placing beneath the cheek of the patient as it lies upon the pillow.

Instruments for the performance of tracheotomy should always be at hand.[1] The accompanying drawing shows a

[1] A case occurred in my own practice some years ago which showed the necessity of being prepared with tracheotomy instruments on *all occasions.* Had I not had a tracheotomy tube with me, it is highly probable that I should not have been able to rescue the patient from imminent death. The case is fully described on p. 450.

convenient **emergency case** which contains not only the appliances which have already been referred to (Mason's gag, tongue-forceps, wooden mouth-opener, and mouth-prop), but instruments for the performance of tracheotomy, viz. two tubes, a scalpel, a sharp hook, and a pair of dressing-forceps which answer as dilators.[1]

FIG. 12.—Emergency Case, containing Mason's Gag, Tongue-forceps, Wooden Wedge, Mouth-prop, Instruments for performing Tracheotomy, Hypodermic Syringe, and partition for remedies such as Nitrite of Amyl, Digitalis, Strychnine, etc.

In **dental practice** the anæsthetist should have with him **several mouth-props** for keeping the teeth apart during the administration of nitrous oxide. Having tried numerous kinds, I devised the prop shown in Fig. 13. It is made of aluminium, and is so shaped that it adjusts itself to the angle made by the lower jaw receding from the upper. It is furnished with detachable rubber pads, which can be renewed from time to

[1] This little case is manufactured by Messrs. Krohne and Sesemann, and is specially adapted for use in operating theatres and elsewhere when anæsthetics are being employed.

time. When in position it engages several teeth, so that there is no chance of a faulty loose tooth being injured. Five sizes are necessary. All props containing springs or screws are liable either to break, to get out of order, or to be contaminated with blood and other unpleasant matters. The props shown can be easily sterilised by boiling. All wooden or vulcanite props, although apparently less cumbrous than those recommended, will be found to more frequently slip than the props shown in the figure.

2. **Remedies.**—Various medicinal remedies have been advocated for the treatment of alarming symptoms during or after anæsthesia, and opinions are still divided as to their relative efficacy. As will be subsequently pointed out (Part

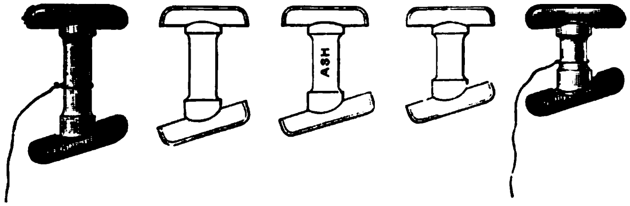


FIG. 13.—Set of five of the author's Mouth-props for use in dental practice (half size).

IV.), the establishment of a free air-way, artificial respiration, and inversion are of far greater value than any other restorative measures with which we are acquainted. The question nevertheless arises, Are there any particular remedies which we should have by us before administering a general anæsthetic —remedies which may be advantageously used, not in the place of those all-important measures just mentioned, but as secondary or subsidiary means in the treatment of alarming symptoms? Of the drugs most likely to be of service, **strychnine** and **nitrite of amyl** are perhaps the most reliable, whilst digitalis, in the form of **digitaline**, may be indicated in certain cases. The anæsthetist who wishes to be equipped for all emergencies should certainly therefore be prepared with strychnine for hypodermic use, and with nitrite of amyl for inhalation, although it is to be remembered that such remedies are chiefly if not wholly applicable to the treatment of collapse from other causes than the anæsthetic. **Alcohol, ammonia, ether** for

subcutaneous injection, and **atropine** have one and all their advocates; but in my experience they are practically **useless** in the treatment of any condition which may be brought about by an anæsthetic. A cylinder of compressed **oxygen** may with advantage be kept in readiness in public institutions in which anæsthetics are given on a large scale, as cases occasionally arise in which the inhalation of this gas is likely to prove of value. A **syringe for the intravenous injection of saline fluid** should also be at hand when dealing with cases likely to need this line of treatment.

H. ASEPTIC PRECAUTIONS. CLEANSING AND DISINFECTING APPARATUS AND APPLIANCES

Although it might be going too far to say that there is as great a need for the observance of aseptic and antiseptic principles in the administration of anæsthetics as in surgery proper, it is highly important that such principles should, as far as possible, be adhered to. Whilst in the ordinary run of surgical cases it is unnecessary for the anæsthetist to do more than thoroughly cleanse his hands and to see that the inhalers and appliances he employs are scrupulously clean before use and carefully washed afterwards, there are certain cases in which special care and precautions must be adopted. These will be presently referred to.

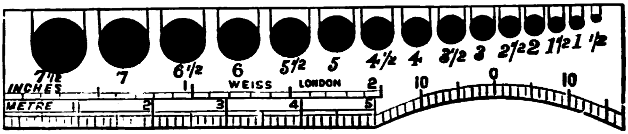
All inhalers and other apparatus should be capable of being thoroughly washed, and any whose mechanism might be injuriously affected by hot water should be discarded as unsuitable. It would be impossible, even were it advisable, to sterilise after each administration the face-pieces, bags, etc., employed. But in general surgical practice it should be a matter of routine, immediately the administration is at an end, to twice wash in hot water everything that has been used; and should any of the apparatus employed have been contaminated by pus, blood, vomited matters, etc., hot weak carbolic lotion (about 1 : 60) may be advantageously substituted for the plain water. It is a mistake to suppose that Clover's inhaler is likely to be damaged by this simple cleansing process. It has for years been my practice to immerse all

parts of this inhaler in hot water immediately after the administration.

Special precautions are necessary when anæsthetising patients for operations upon the head, face, mouth, nose, throat, neck, and shoulders. In such operations the surgeon and anæsthetist are brought into close relations with one another, and it is the duty of the latter, by preparing his hands, and carefully disinfecting, and if possible sterilising, his appliances, to adapt himself to the requirements of the former. Thus, prior to an operation within the mouth, nose, or throat, gags, props, and mouth-tubes should be boiled, and perfectly new sponges, which have previously been placed in 1 : 20 carbolic lotion and have subsequently been washed out, should be in readiness. In operations about the face and neck, the Skinner's mask should either be sterilised before use, or its edges protected by sterilised lint or gauze wound round the circumference of the mask, and pinned.

PART III

THE ADMINISTRATION



PUPILLOMETER.

(By kind permission of Mr. Edgar A. Browne.)

CHAPTER IX

NITROUS OXIDE

In the infancy of nitrous oxide, that is to say, before its anæsthetic properties were fully realised, it was rarely if ever inhaled in a state of purity. Not only was there difficulty in obtaining it in this state, but when obtained it was inhaled in such a way that considerable quantities of air also gained admission to the lungs. It thus happened that the effects produced were usually those of intoxication rather than of anæsthesia, although, as on the memorable occasion when Horace Wells himself inhaled "laughing gas," complete unconsciousness was sometimes induced. By the time that this anæsthetic had found its way to England, Colton's[1] experience had become so great that he was able to formulate rules for its successful administration in dental practice. He urged the necessity of excluding all atmospheric air, and of administering the gas by means of an apparatus with inspiratory and expiratory valves. But whilst air-exclusion was thus rigidly practised when employing nitrous oxide for such short operations as those of dentistry, cases were from time to time recorded in which, by the alternate inhalation of nitrous oxide and air, it was found possible to maintain more or less complete anæsthesia for protracted surgical operations.[2] Clover pointed out the advantage, in such cases, of allowing air to be breathed concurrently with the nitrous oxide; and we are indebted to him for many improvements in inhaling apparatus.[3] By the use of a nose-piece, Clover and Coleman introduced the

[1] *Brit. Journ. Dental Science*, 1868, p. 257.

[2] See *Brit. Journ. Dental Science*, 1868, pp. 393 and 485; and 1869, p. 46. Also *Brit. Med. Journ.*, 2nd May 1868. Also Turnbull's *Artificial Anæsthesia*.

[3] *Brit. Journ. Dental Science*, Sept. 1868, p. 485.

system of maintaining anæsthesia during prolonged dental operations—a system which has, in more recent times, been successfully revived (p. 242). In 1868 Dr. E. Andrews[1] of Chicago published several cases in which by mixing oxygen with nitrous oxide he had obtained a more satisfactory form of anæsthesia than with nitrous oxide alone; but, curiously enough, his interesting observations failed to attract the attention they deserved; and it was not indeed till ten years later that Paul Bert again drew attention, by a series of interesting experiments to be subsequently described, to this system of anæsthetisation. Bert's researches led him to believe that in order to obtain nitrous oxide anæsthesia in the presence of oxygen or air, it was necessary that the patient should be subjected to an increased atmospheric pressure; but experience has proved that this increased pressure is not absolutely necessary. It is now established beyond all doubt that by employing certain percentages of atmospheric air with nitrous oxide a better form of anæsthesia can be obtained than with the undiluted gas; and that by using oxygen instead of atmospheric air, a still better form of anæsthesia is obtainable. There is, in fact, no doubt whatever that the complete exclusion of oxygen, which was at one time considered imperatively necessary, is opposed to those general principles which should guide us in administering anæsthetics.

It will be convenient to consider nitrous oxide under the following sections:—

Section I. The administration of pure nitrous oxide;

Section II. The administration of definite mixtures of nitrous oxide and air;

Section III. The administration of nitrous oxide with indefinite quantities of air;

Section IV. The administration, at ordinary atmospheric pressures, of definite mixtures of nitrous oxide and oxygen;

Section V. The administration, under increased atmospheric pressures, of definite mixtures of nitrous oxide and oxygen (Paul Bert's system); and

Section VI. The administration, at ordinary atmospheric pressures, of nitrous oxide with varying proportions of oxygen.

[1] *Brit. Journ. Dental Science,* 1869, p. 22.

SECTION I.—THE ADMINISTRATION OF PURE NITROUS OXIDE

A. APPARATUS AND METHODS OF ADMINISTRATION

Nitrous oxide is supplied by the manufacturers in iron and steel **cylinders** which contain the agent in a liquid state under considerable pressure.[1] Those yielding 50 gallons of gas are most commonly used; but 25-gallon cylinders are preferable when, as is often the case, portability is a matter of consideration. 100-gallon cylinders are more adapted for hospital practice. Every cylinder is furnished with a label stating its weight when empty and when fully charged; so that, when weighed, the quantity of nitrous oxide present may always be ascertained if desired. 7½ oz. of liquid nitrous oxide will furnish about 25 gallons

FIG. 14.—Two Side-valve Cylinders, with Stand, Double Union, and Foot-key.

of gas. Full, or nearly full, cylinders may at once be known by the liquid sound which they emit when sharply tapped with the foot-key or some similar article. It is always advisable to have two cylinders coupled together, in case one should work badly or fall short during the administration. It is also a good plan to make it a rule on all occasions to work first from the cylinder of one side, and only to go on with the second or reserve cylinder in the event of the other becoming exhausted. If the administrator work indiscriminately from both cylinders he may easily allow the supply of the anæsthetic to fall too low. Care should be taken to thoroughly turn off the gas after each administration, otherwise leakage will gradually occur and the cylinder become empty. Each cylinder is furnished with a screw-valve or tap, by turning which with a foot or hand-key, gaseous nitrous oxide escapes.

Fig. 14 shows two cylinders coupled together. I have had a

[1] I have been informed by one of the manufacturers of the gas that the pressure within the cylinders which they supply often registers nearly 1000 lbs. to the square inch.

lengthened experience with these side-valve cylinders, and believe them to be better than any others. They have the great advantage that they require but a very simple form of stand to render them perfectly stable whilst being worked; and when fitted with the easily acting valves invented by Messrs. Barth and Co. they answer every requirement. It is only quite recently that these side-valve cylinders have been brought into a state of perfection. When they were first used they were not satisfactory; and to the late Dr. C. E. Sheppard belongs the credit of removing the objections which were formerly attached to their use.[1]

Some years ago[2] I made a special study of the various methods then in use for administering nitrous oxide. I came to the conclusions—(1) That accurately fitting valves were essential at the commencement of the inhalation, in order to make sure of the rapid exit of air from the lungs; (2) that, so far as the available resulting anæsthesia was concerned, there was a decided advantage in allowing a certain amount of re-breathing of nitrous oxide towards the *end* of the inhalation; (3) that although there were certain hygienic objections to this re-breathing, it was nevertheless very convenient to be able to resort to it as a measure for securing a longer anæsthesia, or for successfully terminating an administration when the supply of nitrous oxide had unexpectedly fallen short. There was no apparatus which would allow of two valves being in action for the earlier or middle stages of the administration and would subsequently permit re-breathing. I therefore devised[3] and used a face-piece with thin rubber valves which could, at the will of the administrator, be thrown out of action, and allow of the gas-bag being used very much as Clover's "supplemental bag" was used,[4] *i.e.* for to-and-fro breathing. Subsequently I placed these rubber valves in a little box between the stopcock and the face-piece,[5] so that plain valveless face-pieces could be attached. The valves were thrown into and out of action at will by turning a small handle surmounting the valve-box. A short trial of this apparatus led to my placing the valves and the two-way stopcock *in one chamber*, in other words, to the apparatus

[1] See an interesting paper by Dr. C. E. Sheppard, *Lancet*, 21st Feb. 1891. p. 424—"Difficulties connected with the Use of Nitrous Oxide Bottles in the Horizontal Position." Dr. Sheppard found that the 50-gallon cylinders supplied by Messrs. Barth and Co. had a capacity of 50·5 cubic inches, and taking the sp. gr. of the liquid to be ·908 at 45° F. and the weight of the 50 gallons of nitrous oxide gas thus liquefied to be 15 oz., the space occupied in the bottle by the liquid was 28·6 cubic inches, roughly three-fifths of the total capacity. He argued that as the cold produced by the nitrous oxide passing from the liquid to the gaseous form is very intense, superficial solidification of the nitrous oxide may take place, and the snow-like body thus formed may temporarily choke the tube. By bringing the inner orifice of the exit tube above the level of the liquid in the cylinder, all choking with liquid or solid nitrous oxide is obviated.

[2] See "An Inquiry into Several Methods of administering Nitrous Oxide" (*Journ. Brit. Dent. Assoc.* vol. vii., 1886, p. 86).

[3] *Lancet*, 9th May 1885.

[4] *Brit. Med. Journ.*, 14th February 1874.

[5] See *Brit. Med. Journ.*, 27th August 1887, p. 452.

which I now employ, and which I believe to be better than all others for the administration of nitrous oxide (Figs. 15, 16, and 17).

The apparatus which I have found to give the best results in the administration of nitrous oxide is shown in the accompanying figure. It is made for me by Messrs. Barth and Company. From the single union (*su*) the tube (*t*) passes to join the bag (B).[1] A little stopcock (*s*) is useful in case it should be wished to disconnect a full bag from the rest

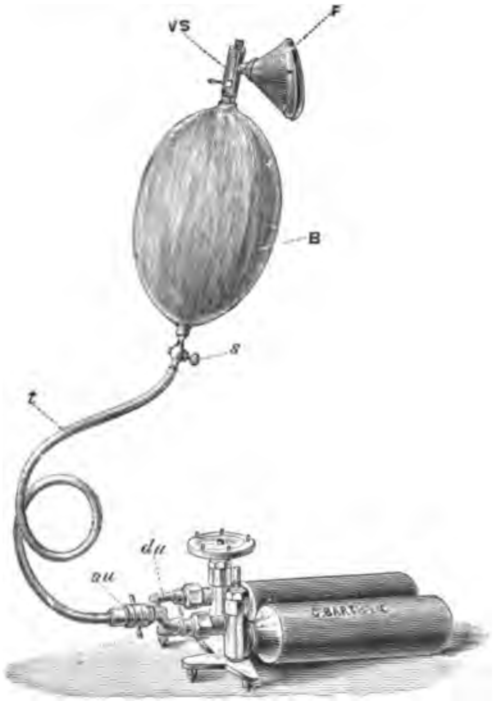


FIG. 15.—Complete Apparatus for the Administration of Nitrous Oxide Gas.

of the apparatus. The bag (B) has a capacity of about 2 gallons. There is certainly an advantage in having the bag as near as possible to the face-piece; for not only can its movements be readily watched, but the patient can take the most forcible inspirations without any of that impediment which is likely to be experienced when a tube exists between the bag and face-piece. The valved stopcock (VS), which is the most important part of the apparatus, connects the gas-bag (B) to the face-piece (F). This stopcock, shown more in detail in Figs. 16

[1] Some administrators interpose what is known as a "quieter" between the gas cylinders and this tube, but when properly managed the noise of issuing gas is so slight as to render such a complication unnecessary.

and 17, contains two thin valves of sheet india-rubber, which may be thrown into or out of action by turning the tap T. The handle H determines whether air or gas is admitted to the face-piece. When T and H are arranged as in Fig. 16, air enters the stopcock and is breathed out through valves in the direction shown by the arrows. Fig. 17 shows in diagrammatic section the mechanism of the valved stopcock. It has two slots cut out of its circumference, an upper slot (US) and a lower slot (LS). There are two inner cylinders which revolve immediately inside the outer casing of the stopcock. The upper inner cylinder (UIC) is worked by T, the lower (LIC) by H. The upper cylinder carries the inspiratory and expiratory valves (IV and EV). The lower has a slot in its walls (shown in dotted lines) which can be made to correspond with LS by turning H. When T is turned as in the diagram the upper slot is open, both valves act, and expirations escape as shown by the arrow. When T is turned completely round, the upper inner cylinder rotates, the valves are thrown out of action, the upper slot is closed (as shown by dotted line), and to-and-fro breathing results. Whether air or nitrous oxide be admitted to the face-piece is determined by the position of H. When H is placed as in the diagram the inner cylinder which it controls allows of a free passage of gas from the bag to the face-piece (as shown by the long arrow). Should H be moved round, the inner cylinder would cut off the way to the bag and would open the air slot (LS), so that air and not gas would be respired (Fig. 16). The valved stopcock therefore permits—

FIG. 16.—The author's Valved Stopcock, with Face-piece, etc., for administering Nitrous Oxide.

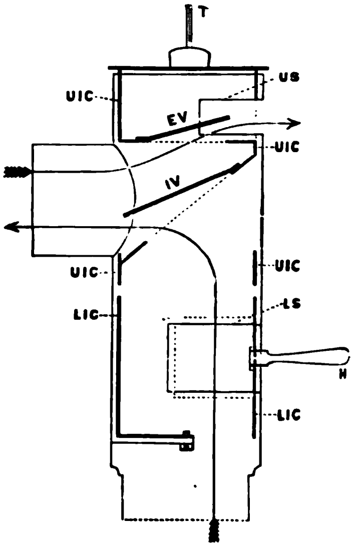


FIG. 17.—Diagrammatic Section of the author's Valved Stopcock.

(1) *Air* to be breathed { (*a*) *through valves*, or (*b*) *backwards and forwards.*

(2) *Nitrous oxide* to be breathed { (*a*) *through valves*, or (*b*) *backwards and forwards.*

In actual practice we arrange the stopcock so that the patient may first of all breathe air through valves, and then nitrous oxide through valves; and we only call into play the to-and-fro breathing of nitrous oxide under special circumstances, to which future reference will be made. The arrows in Fig. 16 indicate the direction taken by the air current when the face-piece is applied to the face, *i.e.* before nitrous oxide is turned on by the handle H. The valves should work easily. They should be examined before use to see that they do not stick and that they have in no way become caught in the orifices which they guard. The whole stopcock has wide channels through it, in order that respiration may take place freely. This is especially necessary with regard to the air-hole, so that when the apparatus is applied to the face the patient may feel no impediment in filling his chest with air. Most of the older forms of apparatus have channels far too small for successfully administering nitrous oxide gas. The face-piece should be furnished with a broad soft air cushion, which should be partly distended with air by means of the little tap for the purpose. Two or three sizes are necessary. The angle of the face-piece cushion, into which the bridge of the nose fits, should be acute, in order that the face-piece may accurately fit the patient. No apparatus can be considered satisfactory unless it allows the patient to *breathe air through valves* before nitrous oxide is turned on. The reason for this statement will be presently discussed.

In **administering nitrous oxide** the following directions must be observed:—

1. *Make sure that there is a sufficient supply of gas before commencing.* Patients vary as to the quantity of nitrous oxide required to produce anæsthesia. The average may be roughly placed at six gallons per patient. Tall, plethoric, or alcoholic subjects may require considerably more than this. When there is much hair around the mouth it is often difficult to wholly exclude atmospheric air, and hence more nitrous oxide than usual may be needed. In such cases it is a good plan to moisten the moustache or beard before applying the face-piece, and to keep up a greater pressure than usual within the gas-bag. Anæmic and feeble subjects, as well as children, may usually be anæsthetised by three or four gallons of the anæsthetic.

2. *Run a small quantity of nitrous oxide through the apparatus to free it from air; fill the bag to about two-thirds with the gas; and then turn off the screw-valve of the cylinder.* The apparatus is now charged and ready for use. All the above arrangements should if possible be made out of sight of the patient.

3. *Breathe through the face-piece in order to make sure that the valves are acting efficiently.*

4. *Adjust the mouth-prop, should one be necessary* (see p. 164).

5. *Gently apply the face-piece to the face of the patient.* Success in giving nitrous oxide largely depends upon the accuracy with which the face-piece fits. The best test as to the fitting is the soft regular sound made by the valves. It is usually a good plan to tell the patient that he is simply breathing air, and to request him to take "long deep breaths, in and out, through the mouth." Should the face-piece not fit well, the particular sound made by the particular apparatus when its valves work freely, and when it fits the face, will not be produced; and the face-piece must be readjusted. Never turn on nitrous oxide till it is quite certain that the face-piece fits, and that the patient is breathing air freely. Some patients hold their breath and pretend to be breathing deeply when in reality they are not doing so. Unless the patient can be made to freely fill his chest with air he certainly will not inhale nitrous oxide when the latter is substituted. The administrator may often get a patient to breathe freely by showing him how to respire.

6. *When the patient is observed to be freely filling his chest with air through the apparatus, nitrous oxide may be turned on.* At the moment that this is done the gas-bag must not be over-distended: it should be about two-thirds full. In some forms of apparatus now made, the patient, in the first instance, breathes air *in and out* through a slot and not through valves. All such forms of apparatus are constructed on erroneous principles. The transition from air through valves to gas through valves is hardly noticed by the patient; the same sound is made and the same feelings are experienced in filling the chest. But if a patient is first allowed to breathe air in and out through a slot, and is then made to breathe nitrous oxide through valves, the transition is more noticeable to him, and more likely to disturb his breathing.

7. *The bag should be kept nearly full throughout the administration.* At the same moment that nitrous oxide is admitted, the administrator should gently allow a stream of gas to enter the bag from the bottle. Fig. 18 shows the administration of nitrous oxide for a dental operation by means of the apparatus

which I find to answer best. An attempt should be made to give the gas as nearly as possible slightly above atmospheric pressure. Any evidence of excitement must be followed by a slight increase in the pressure of the bag, as such symptoms are probably due to the ingress of air by the side of the face-piece. In the case of tall strong men it is best to keep up a slight positive pressure throughout; whereas in weakly

FIG. 18.—The Administration of Nitrous Oxide for a Dental Operation (from a photograph).

patients and children the reverse plan may be followed. Increased pressure in the gas-bag probably only affects the administration in so far that it prevents the smallest quantity of air gaining admission with the gas, whilst with diminished pressure a small percentage of air probably obtains admission. It is, at all events, certain that whilst a small quantity of air is prejudicial to a successful anæsthesia in vigorous subjects, such a dilution of the gas is often advantageous in fragile persons and children.

8. *To-and-fro breathing of nitrous oxide should not be permitted except under certain circumstances, and then only towards the end of the administration.* A great deal of discussion has taken place as to the propriety of allowing the patient to re-breathe nitrous oxide. The matter admits of consideration from two points of view, which may be called (*a*) the hygienic, and (*b*) the practical. From the hygienic point of view, we must all admit that, as a routine procedure, the re-breathing of nitrous oxide is not to be recommended. It is next to impossible to thoroughly cleanse nitrous oxide bags after every administration; and we are certainly not justified, whatever may be the advantage of the plan, in allowing one patient to inhale from a bag into which another one has just been breathing. From the practical point of view, however, the question assumes a totally different aspect. I am not referring to to-and-fro breathing *early* in the administration; this is, of course, inadmissible by reason of the dilution of nitrous oxide which would result from its admixture with the considerable proportion of atmospheric air previously contained in the air-passages of the patient. I refer to to-and-fro breathing towards the *end* of the administration, *i.e.* when most of the air has been washed out of the air-passages by the free inhalation and exhalation of nitrous oxide through valves. For the sake of clearness let us suppose that we have six gallons of nitrous oxide ready for an administration. We allow the patient to breathe four gallons of this through valves, so that his lungs rapidly lose nearly all the air which they contained, and all expirations escape into the surrounding atmosphere. The valve-action is now stopped, and the patient is made to breathe the remaining two gallons of nitrous oxide backwards and forwards into the bag. Anæsthesia will take a little longer to become established than usual, because of a small percentage of oxygen (from the residual air of the lungs) being still in the to-and-fro current. Had no to-and-fro breathing been permitted, the phenomena of nitrous oxide anæsthesia would have come on earlier, because of the quicker expulsion of all oxygen. Now, the longer inhalation leads to a longer available anæsthesia, so that from some points of view this plan of administering nitrous

oxide has distinct advantages. That the re-breathing *towards the end of the administration* has no bad effect upon the patient I have proved by a very large number of administrations. I have found, it is true, that the recovery is not quite so rapid as when nitrous oxide is continuously inhaled in the usual manner; but this slight difference is connected with the longer period of inhalation. The longer we allow a patient to inhale an anæsthetic, the longer, as a rule, will he be in regaining complete control and consciousness. Some have objected that this method of re-breathing towards the end is more "asphyxiating" than the ordinary method. But the reverse is more correct if by "asphyxiating" is meant the occurrence of symptoms dependent upon the deprivation of oxygen. Were it not, therefore, for the hygienic objections above alluded to, the plan of administering nitrous oxide just described would certainly have advantages over others.[1]

B. THE EFFECTS PRODUCED BY NITROUS OXIDE WHEN ADMINISTERED FREE FROM OXYGEN

Owing to the rapidity with which the phenomena of nitrous oxide narcosis make their appearance, there is greater difficulty in arranging them in groups, and in recognising degrees or stages in the administration, than in the case of ether or chloroform. But from the fact that nitrous

[1] I have analysed the contents of the gas-bag, at the end of an administration, after to-and-fro respiration, and have found from 1·2 to 2·4 per cent of oxygen in a two-gallon gas-bag which, from the moment when to-and-fro breathing commenced to the termination of the administration, remained full or nearly full. Full details of the experiments are given in the *Journ. Brit. Dent. Assoc.* vol. vii., 1886, p. 86. I once administered nitrous oxide to a patient on six different occasions. On three of these I adopted the ordinary method, allowing the valves to act throughout, and all expirations to escape. On the three other occasions the patient was anæsthetised by allowing her expirations for the first and major part of the inhalation to escape, and then, when the lungs had been well washed out with gas, to-and-fro breathing was permitted. The times (*a*) of inhalation and (*b*) of resulting anæsthesia were taken on each occasion, and are of much interest as showing the slight but distinct gain in available anæsthesia when to-and-fro breathing is permitted towards the close of the administration (see *Journ. Brit. Dent. Assoc.* vol. vii., 1886, p. 342). The average available anæsthesia in the absence of to-and-fro breathing was 39 seconds; whilst when to-and-fro breathing was permitted, as described, a workable anæsthesia of 56 seconds was obtained.

oxide, more particularly when administered with oxygen, closely resembles ether and chloroform, it has been thought best to adopt the same plan that will be followed when describing the phenomena which attend the administration of the last-named agents. In order that comparisons may be drawn between nitrous oxide on the one hand and ether or chloroform on the other, we must either disregard as not bearing upon the question those phenomena which in the case of nitrous oxide administered *per se* are dependent upon temporary absence of oxygen, or, better still, we must compare the anæsthesia of nitrous oxide *plus* oxygen (see p. 258) with the anæsthesia of agents which are also administered with this gas, *i.e.* with atmospheric air.

First Degree or Stage.—Nitrous oxide has a peculiar sweetish taste which is by no means unpleasant. Great variation will be found to occur in the sensations which patients experience during the inhalation of this agent. When administered in the proper manner, and with due attention to details, these sensations will be more likely to be of an agreeable than of a disagreeable character. Should the apparatus possess valves which do not work easily, or should the channels through which the gas is made to pass be too small, or should the patient from want of confidence or knowledge breathe in a shallow and restrained manner, an unpleasant experience may result. A feeling of warmth in the lips, and an indescribable though pleasant numbness over most of the body, are amongst the first sensations noticed. The patient has an irresistible desire to breathe more deeply and quickly. These sensations are rapidly followed by a peculiar and pleasurable "thrilling" which hardly admits of description. Almost identically the same sensations mark the first stage of chloroform inhalation. Some tinnitus may be present, and curious sensations, such as fulness and expansion of the head, are occasionally experienced. As a general rule, however, loss of consciousness comes on before the patient has time, so to speak, to define his feelings. The respiration will be observed to be deepened and quickened in response to the desire of the patient just alluded to. The pulse, as Sir George Johnson pointed out, grows fuller under

the finger; and, according to Dr. George Oliver,[1] its calibre is somewhat increased at this stage. The increased fulness is probably due to constriction of the systemic arterioles. The power of hearing persists throughout this stage. The time which elapses between the commencement of the inhalation and loss of consciousness is extremely short, being probably about 20-30 seconds on the average.

Second Degree or Stage.—With the loss of normal consciousness, disturbed psychical states are liable to arise. As a general rule the patient gives little or no evidence of such disturbance, more especially if allowed to remain perfectly quiet. If roughly handled he is liable to become excited and to move his arms or legs. When nitrous oxide is properly administered symptoms of excitement are, with the rarest possible exceptions, conspicuously absent. Any injury inflicted during this stage may produce immediate reflex effects, such as shouting, co-ordinate or inco-ordinate movement, but would not be accurately remembered by the patient. Nitrous oxide is often accused of producing imperfect anæsthesia, because operations are sometimes commenced at this stage. Dreams are frequent, but are rarely distinctly remembered. Sometimes they are so pleasant that, at the conclusion of the administration, the patient, who is unaware of having been deeply anæsthetised, is sorry to be disturbed. On other occasions dreams are of the most disagreeable character. It is a curious fact that unpleasant dreams are more common under nitrous oxide *per se* than under nitrous oxide administered with oxygen—probably because the anæsthesia in the latter case is deeper, so that operations or other interferences which in the case of nitrous oxide itself might leave some disturbed impressions, are not capable of doing so when the narcosis is more profound. Erotic dreams are occasionally experienced.[2] The respiration is still quicker and deeper than normal, and, save perhaps for an occasional act of swallowing, is perfectly regular. In some cases a spurious form of stertor may occur and is to be disregarded. The pulse is still full and a trifle quicker than in the previous stage. The conjunctiva is quite sensitive to touch. The pupils usually grow larger as the

[1] *Pulse-gauging*, 1895, p. 82. [2] See *Lancet*, vol. ii., 1872, p. 721.

administration proceeds. The features gradually lose their normal colour. Duskiness or lividity is most common in patients of a florid type, anæmic and sallow persons showing very little alteration in appearance. The eyelids are usually affected by slight twitching; and as the inhalation proceeds they exhibit a tendency to separate and to display the subjacent globes.

Third Degree or Stage.—The first indication that the patient is passing or has passed into the third stage of anæsthesia is usually afforded by the **respiration.** The breathing, which has hitherto preserved its rhythm, now loses it, and a peculiar and characteristic throat-sound, sometimes described as "stertor," becomes audible.[1] This sound is most probably due to irregular and spasmodic elevations of the larynx towards the epiglottis and base of the tongue, and indicates a tendency to obstruction in the air-way at this point. Deep snoring or snorting breathing may be met with in certain cases, and may either necessitate the withdrawal of the anæsthetic before the time has come, so to speak, for the deeper throat-sound, or may altogether mask the latter. As has been pointed out, the position of the head and the conformation of the upper air-passages will have an important bearing on the presence or absence of stertor. At or about the moment at which the characteristic guttural sound occurs, the rhythm of breathing is liable to be further interfered with by clonic spasm of thoracic and abdominal muscles. Sometimes, indeed, a sudden irregularity in breathing, totally independent of laryngeal closure or "stertor," and entirely the outcome of this muscular spasm, may be the first indication of deep anæsthesia. It occasionally though rarely happens that, instead of respiration undergoing the changes mentioned, it becomes somewhat feeble; or expiration becomes prolonged and rather stridulous. These phenomena should, in the presence of other signs of anæsthesia, be taken to mean that the administration has been pushed sufficiently far. I found by timing 60 consecutive nitrous oxide administrations that the average number of respirations required to produce deep anæsthesia was 29·2. The lowest recorded number was 6;

[1] The word "stertor" should, I think, be confined to *snoring* sounds.

the highest 72. It need hardly be pointed out that it is very exceptional for deep anæsthesia to follow after only six inspirations of the gas; but the number is quoted in illustration of the fact that a very small quantity of this, as of other anæsthetics, is sometimes needed in order to produce the usual phenomena.

The **circulation** is well maintained during nitrous oxide narcosis, provided that care be taken to prevent too great a degree of asphyxiation. From the observation of a considerable number of cases I have found that, in most instances, the heart's action becomes more and more accelerated as the administration proceeds, and that, when the usual phenomena of nitrous oxide narcosis occur, the pulse is often very rapid, especially in those whose cardiac action was quick at the commencement of inhalation. A pulse of 120 immediately before the administration may, for example, rise to 160 or more when clonic movements, etc., occur; whereas a pulse of 80-90 at the beginning of the inhalation will often not exceed 100 or 110 in the third stage. As the pulse increases in frequency it loses its previous fulness; and this change is of course most conspicuous in patients with quick cardiac action. According to the late Sir George Johnson,[1] the small pulse observed at the acme of the inhalation is due to less blood reaching the left side of the heart. Immediately air is admitted by the withdrawal of the anæsthetic, the pulse undergoes a marked change. It at once becomes slower and fuller. A pulse of 140 at the acme of anæsthesia may thus suddenly drop to about 80 per minute before the effects of the anæsthetic have passed off. As consciousness becomes restored, the pulse-rate again rises, being influenced by mental conditions, after-pain, etc.

With regard to the **muscular phenomena** considerable variation exists. The extremities are sometimes, though by no means invariably, flaccid. When respiration undergoes the changes above referred to, the arm, if raised by the administrator, will generally fall. But there is a tendency, when nitrous oxide has been administered to its fullest extent, for clonic muscular contractions to occur in all cases, and for tonic spasm to arise in many. In the course of a recent

[1] *Brit. Med. Journ.*, 21st and 28th April 1894.

investigation I showed[1] that the so-called "jactitation" of nitrous oxide, which may vary from a slight subsultus to a widely-diffused epileptiform seizure, is an intercurrent condition due to want of oxygen, and not an essential feature of true nitrous oxide anæsthesia. In some cases the facial muscles are chiefly affected by the convulsive seizure; in others the whole body mildly oscillates, the spasm apparently chiefly affecting the trunk muscles; in others, the hands, legs, and arms alone may twitch; whilst in a fourth group of cases the neck may be affected by barely perceptible clonic spasm, so that the head is felt to move with fine rhythmic jerks in one or other direction.

There is little doubt that the intermittent elevation of the larynx, the irregular contractions of the thoracic and abdominal muscles, and the clonic movements of the extremities are correlated. Tonic muscular contraction is sometimes very pronounced, not only in the extremities but in the neck, back, and other parts; some patients, indeed, pass into an opisthotonic condition during this stage. Micturition very rarely occurs, but is sometimes met with in children when the clonic movements are at their height. Defæcation is extremely uncommon. Victor Horsley has shown[2] that in deep nitrous oxide narcosis the superficial plantar reflex is abolished, but the deep patellar reflex is maintained. Eulenburg's experiments[3] also show that in the asphyxial state, whether induced mechanically or by drugs such as nitrous oxide, the superficial reflexes disappear before the deep. Dr. Buxton[4] found that one-third of the men, and nearly one-third of the women, anæsthetised by him at the Dental Hospital displayed ankle-clonus under nitrous oxide.

The **pupils** in the majority of cases are dilated in deep nitrous oxide anæsthesia. In some cases, even though the anæsthetic has been freely administered, they remain of moderate size or even contracted.

[1] See "On the Effects produced in the Human Subject by the Administration of Definite Mixtures of Nitrous Oxide and Air, and of Nitrous Oxide and Oxygen" (*Trans. Royal Med. Chi. Soc.* vol. lxxxii. p. 163).

[2] *Brain*, vol. vi. p. 369.

[3] *Centralblatt für med. Wissensch.* No. 6, 1881.

[4] *Brit. Med. Journ.*, 24th September 1887.

The **conjunctival reflex**, which will have persisted during most of the administration, now either becomes less marked or disappears. It cannot be depended upon as a guide, for it may sometimes be elicited even when wide dilatation of the pupils, and other signs indicative of the anæsthetic having been pushed as far as is advisable, are present. The corneal reflex usually persists.

The **colour of the features** is invariably altered, the change being most noticeable at the height of the muscular phenomena. Flabby and apoplectic-looking patients usually become deeply cyanosed when fully anæsthetised by nitrous oxide.

C. TIME TAKEN TO PRODUCE DEEP ANÆSTHESIA

The time taken to produce deep anæsthesia varies considerably in different subjects. In the investigation above alluded to, I found, by adopting special precautions against the admission of air, and by working with perfectly pure gas, that the average inhalation period of 20 cases, the patients ranging from 39 to 13 years, was 55·9 seconds. The longest inhalation was 72 seconds, the shortest 33 seconds.

Children and anæmic patients may sometimes be deeply anæsthetised in 15 or 20 seconds; whereas, in the case of robust and vigorous subjects, the administration may have to be carried on for from 1 to 2 minutes before signs of deep anæsthesia are witnessed.

If the bag from which the gas is being inhaled be kept slightly distended, anæsthesia will ensue more rapidly than if the supply of the anæsthetic be less freely maintained. This is probably owing to the impossibility of any atmospheric air gaining admission to the lungs whilst a positive pressure is being kept up in the gas-bag. We should endeavour to administer nitrous oxide as nearly as possible at atmospheric pressure, neither allowing the bag to become too much distended nor permitting it to become so nearly exhausted as to cause a slight exertion on the part of the patient in drawing out the gas from the bag.

D. THE DEPTH OF ANÆSTHESIA NECESSARY FOR SURGICAL OPERATIONS

When pure nitrous oxide is administered in such a manner that every expiration escapes into the surrounding air, it is often a matter of some difficulty to decide at what particular moment anæsthesia is at its height. As a general rule it is best to wait until stertor or slight clonic muscular twitching is produced. In dental practice the administration may be conducted till two or three stertorous breaths have taken place, but when the oral or nasal cavity is not to be involved in the operation the surgeon may commence his incision or any other procedure when stertor first becomes audible. For reasons already given (p. 216), to-and-fro breathing towards the close of a nitrous oxide administration is advantageous in many cases, postponing as it does the onset of stertor and jactitation, and therefore leading to a more lengthened available anæsthesia-period. In the absence of any re-breathing, asphyxial phenomena are prone to arise before conjunctival reflex is lost; but when re-breathing is permitted, the administration may usually be continued till the conjunctiva loses its sensibility, and as there will be less stertor and muscular movement, the results will be better from the surgical point of view. With some patients, and especially with children, alcoholic subjects, and those who from some special reason have become very susceptible to oxygen deprivation, asphyxial symptoms may ensue before the gas has had time, so to speak, to produce anæsthesia, and if a tooth be extracted or an incision made at what would appear to be the height of anæsthesia, reflex phenomena of an inconvenient kind will arise. I have met with two or three cases in the course of my experience in which it seemed to be impossible to produce that absolute and dreamless unconsciousness which is attainable with other anæsthetics.

Operations should never be begun till as deep an anæsthesia as possible has been secured; and should the anæsthesia prove to be of insufficient duration for the completion of the operation, the latter should be discontinued before the patient

passes into the analgesic state which immediately precedes recovery.

Although the extraction of a tooth during imperfect anæsthesia may not give the patient the sensation which we call pain, the operation may, under such circumstances, produce such a horrible and ill-defined feeling, or give rise to such an unpleasant dream, that it is questionable when anything has been gained by the inhalation. In addition to these considerations, the performance of an operation during imperfect anæsthesia may be attended by much inconvenient tonic muscular spasm, which, in dental surgery, is objectionable from the liability of extracted teeth, etc., to fall backwards during opisthotonos.

In one or two cases I have known prolonged and somewhat difficult expiration to replace other signs of narcosis. I have, moreover, met with cases in which, just at the acme of anæsthesia, the patient has made a sudden attempt at retching. Under such circumstances as these, the administration should be discontinued. Any marked feebleness of the pulse or respiration should also be taken as an indication to remove the inhaler. Dilatation of the pupils is usually present in deep nitrous oxide anæsthesia, though it cannot be relied upon as a guide.

From the foregoing considerations it is, I think, perfectly clear that pure nitrous oxide administered in the customary manner is not a satisfactory anæsthetic from the surgical point of view. In order to obtain the best results from this agent it is necessary to eliminate the intercurrent asphyxial symptoms which accompany its inhalation, and this can be effected by mixing either air or oxygen with the anæsthetic gas (*vide infra*).

E. RECOVERY-PERIOD: DURATION OF ANÆSTHESIA AFTER INHALATION

With the removal of the face-piece, or with the admission of air by other means, the recovery period commences. Sometimes, and especially in patients who have become markedly stertorous, the withdrawal of the anæsthetic does not neces-

sarily involve the immediate admission of air to the lungs. In other words, a more or less occluded state of the upper air-passages may persist for a while and so retard the usual process of recovery. Other things being equal, the more rapidly and freely atmospheric air gains access to the lungs, the more quickly will the patient recover. One of the first effects of the admission of air is observed in the pulse, which suddenly becomes much slower and fuller. Stertor, anoxæmic convulsion, and lividity now quickly vanish; and the dilated pupils begin to grow smaller. A secondary dilatation of the pupil may often be observed during the recovery period.

The anæsthesia which persists after a single, continuous administration of pure nitrous oxide is known in dental practice as the **available anæsthesia.** In the course of the investigation above referred to, I found that the 20 patients gave an **average available anæsthesia of 30·3 seconds,** the longest anæsthesia being 45 seconds, and the shortest 15 seconds. There is considerable difficulty in deciding when true anæsthesia actually terminates, and this no doubt accounts for the discrepancies in the statements made by various authors. The period of available anæsthesia is to a certain extent dependent upon that of the inhalation; a long inhalation being followed, as a general rule, by a long anæsthesia, and *vice versa.* Moreover, in dental operations the duration of anæsthesia will not unfrequently be found to be influenced by the position of the patient's head, and more especially by the position of his tongue, during the extraction. Should the head be fully extended and the operation upon the upper jaw, nitrous oxide will have every chance of quickly escaping, and consciousness may thus be rapidly regained. If, however, the head be more or less vertical in the chair and the operation upon the lower jaw, nitrous oxide may not escape so freely, by reason of the tongue being pressed backwards.

F. DANGERS CONNECTED WITH THE ADMINISTRATION

From the physiological and clinical facts to which reference has already been made it is clear that nitrous oxide, when administered in its pure state, and in such a manner

that all expirations escape into the surrounding atmosphere, is respirable only up to a certain point. When this point has been reached, oxygen must be admitted to the lungs, otherwise respiration will not proceed. When nitrous oxide is clumsily administered so that the face-piece fails to fit accurately, when more or less re-breathing is permitted, or when the apparatus is faulty in construction, this gas may appear to be continuously respirable. But when all oxygen is rigidly excluded, and at each inspiration pure nitrous oxide enters the lungs, asphyxial phenomena rapidly supervene, and it is these phenomena, whose occurrence is incidental rather than essential, that have to be taken into account in considering the accidents and dangers to which the patient is liable. As will be presently pointed out, the asphyxial symptoms of an ordinary nitrous oxide inhalation become attenuated, or even altogether vanish, when air or oxygen is added to the anæsthetic gas in suitable proportions; and there can be no doubt that, in employing the pure agent, we are, in a sense, committing a physiological error. Why should the patient be subjected to an intercurrent state of asphyxia when that state is not essential to the anæsthesia? In other words, why should we not, whenever we wish to obtain unconsciousness by means of nitrous oxide, obtain that unconsciousness by administering the gas with a suitable proportion of air or oxygen?

Before considering the dangerous conditions which may arise under pure nitrous oxide, it will be well to say something of the fatalities which have been recorded in connection with the use of this anæsthetic. After carefully searching through the medical and dental journals of the past 40 years,[1] and instituting inquiries in other directions, I have only been able to find records of 30 fatalities, and, as will be seen from the subjoined classification, several of these may be excluded. On the other hand, there is every reason to believe that many more deaths have taken place than those which have been reported.

[1] I am much indebted to Mr. Bellamy Gardner and Mr. Nolan Daly for assistance in this work.

Classified Summary of all the obtainable Records of Deaths attributed wholly or partly to Nitrous Oxide

Class A. Deaths undoubtedly due, partly or wholly, to nitrous oxide.

Case 1.—22nd January 1873: Exeter: F. 38: stout: enlarged tonsils and uvula: dental operation: semi-recumbent: double administration: asphyxia. Case 2.—27th March 1877: Manchester: M. middle-aged or elderly: obese: dental operation: double administration: asphyxia. Case 3.—15th September 1883: London: M. 57: tongue enlarged by morbid growth and fixed: dental operation: convulsive tremor and rigidity: asphyxial syncope. Case 4.—Reported in 1885: Paris: M. about 50: dental operation: "syncope." Case 5.—1st October 1887: Edinburgh: F. 71: stout: corsets tight: food in stomach: dental operation: probably asphyxia. Case 6.—1890: Montreal: M. 24: dental operation: "syncope." Case 7.—1st May 1892: Buffalo, U.S.A.: F.: mother of two small children: dental operation: mode of death uncertain. Case 8.—? 1893: Batley: M. 39: small and deformed lower jaw: dental operation: asphyxia. Case 9.—1893: ? place: F. ? age: dental operation: asphyxia, probably favoured by morbid state of upper air-passages. Case 10.—21st February 1894: London: M. 26: enlarged tonsils: receding lower jaw: short neck: dental operation: asphyxia. Case 11.—12th January 1895: Preston: F. 23: tight corsets: full stomach: dental operation: asphyxia. Case 12.—7th October 1895: New York: F. 22: dental operation: ? mode of death. Case 13.—Prior to 1896: Chestnut Hill: M. ? age: dental operation: asphyxia. Case 14.—March 1899: Birmingham: M. 12: large abscess in base of tongue: fixed lower jaw: horizontal posture: extension of head: opening abscess: asphyxia. Case 15.—Reported to me in 1899: London: M. 7: very delicate: old-standing pericarditis and pleurisy: dorsal posture: operation for adenoids: nitrous oxide given with air: head over end of table: syncope: no obstruction in breathing. Case 16.—15th June 1899: London: F. 27: food in stomach: operation on elbow: double administration: vomiting: dusky pallor: "syncope." Case 17.—November 1900: M. 36: suppuration of neck: left tonsil swollen: incision of neck: nitrous oxide with air first given: then pure nitrous oxide: cessation of respiration: death from asphyxia: at necropsy larynx found to be œdematous.

Class B. Cases in which death is stated to have occurred under nitrous oxide, but of which no particulars are given.

Case 1.—1864: ? place: young woman: dental operation. Case 2.—About 1868 or 1870: Louisville. Case 3.—October 1871: Chicago.

Class C. Deaths doubtfully due, partly or wholly, to nitrous oxide.

Case 1.—12th October 1889: Philadelphia: M. 46 : dental operation: died with symptoms of apoplexy five hours after administration. Case 2.—? 1864: New York: M. ? age: lungs much diseased: dental operation: died with pulmonary symptoms two hours after administration. Case 3.—? 1893: Erie: F. ? age: bad state of health: dental operation: recovery of consciousness: death soon after from "œdema of lungs."

Class D. Deaths due to foreign bodies entering the larynx during or after the inhalation of nitrous oxide.

Case 1.—Before 2nd February 1867: ? place: M. 13: dental operation: cork (used as prop) entered larynx: asphyxia. Case 2.—27th April 1882: Preston: M. 10: dental operation: molar tooth entered larynx: asphyxia. Case 3.—(*B.M.J.*, 18th February 1899): tooth entered bronchus: death in twelve days.

Class E. Self-administration.

1893: London: M. ? age: asphyxia from continued application of face-piece.

Class F. Deaths wrongly attributed to nitrous oxide.

Case 1.—Before 26th February 1864: Allentown, Pa.: F.: died a few hours after inhalation. Case 2.—1864: Swanton Falls, Vt.: F. 17: died after inhaling nitrous oxide at the hands of a travelling dentist. Case 3.—20th March 1872: New York: F.: nitrous oxide given, but patient became conscious and dental operation then performed: faintness: vertical posture: fatal syncope.

There are several interesting points in connection with the 17 cases of Class A. Of the first 13 cases, in all of which dental operations were performed, 7 were males and 6 were females. This is an interesting fact, seeing that of the patients who require nitrous oxide for dental operations the great majority are females. The preponderance of males in the table is no doubt dependent upon the greater tendency to dangerous asphyxial spasm in men. The average age of the cases in which the age is given is 33. Perhaps the most interesting and important fact in connection with these deaths is that there was in most of the cases some condition present, before the administration, which rendered the patient liable to a more marked degree of asphyxia than would ordinarily attend an administration of pure nitrous oxide. Thus, in Case 1 the

patient, who was stout, had large tonsils, and was anæsthetised in the semi-recumbent posture (see p. 150). In Case 3 the tongue was enlarged and fixed. In Case 5 the patient, who was stout, had tightly-fitting corsets and food in the stomach. In Case 8 the patient had a deformity of the lower jaw. In Case 9 there was post-mortem evidence of a morbid state of the upper air-passages. In Case 10 there were enlarged tonsils, and the patient had a short neck and receding lower jaw. The corsets were tight and the stomach full in Case 11. In Case 14 the air-way was much encroached upon by an abscess in the base of the tongue; in Case 16 the stomach contained food; and in Case 17 one tonsil was enlarged and there was œdema of the larynx. It is thus clear that in at least 50 per cent of the fatalities undoubtedly attributable, wholly or in part, to nitrous oxide, some pre-existing condition was present which rendered the deprivation of oxygen exceedingly hazardous. The large majority of the patients undoubtedly died with asphyxial symptoms; and it is quite conceivable that, even in those in which the circulation is reported to have failed before the respiration, some unrecognised embarrassment to breathing was present.

It will be convenient to consider the dangerous phenomena which may attend the use of pure nitrous oxide under three main headings: (1) Primary respiratory failure, circulation subsequently ceasing; (2) Primary circulatory failure, respiration subsequently ceasing; and (3) Simultaneous cessation of both respiration and circulation. I purposely avoid speaking, in this clinical section, of *cardiac* failure.

(1) **Primary Respiratory Embarrassment and Failure.**—When an **overdose** of nitrous oxide is administered to a healthy subject **(Fourth Degree or Stage)**, the breathing becomes embarrassed and then ceases, the immediate cause of the embarrassment and failure usually being convulsive muscular spasm, anoxæmic in its nature. In some cases obstructive stertor, of spasmodic origin, asserts itself and brings breathing to a standstill, whilst the conjunctiva is yet sensitive and the patient not fully anæsthetised. In other cases asphyxial spasm of thoracic and abdominal muscles constitutes the main element in the arrest of breathing. The more vigorous the patient, the more powerful will

be the spasm. In tall muscular young men, for example, an opisthotonic state may be induced. Defæcation or micturition may occur. Respiratory failure from paralysis of the nervous mechanism of respiration is rarely if ever met with, at all events in its pure form, in healthy patients subjected to an overdose of this anæsthetic. At the moment when breathing ceases the colour is usually markedly cyanotic or livid, the eyeballs generally turned upwards, the lids separated, and the pupils widely dilated. The character of the pulse at this juncture will depend upon circumstances. For example, should obstructive stertor have come on rather earlier than usual, and be the immediate cause of arrested breathing, the pulse may show but slight evidences of depression. But should more of the anæsthetic have been introduced before breathing ceases, the pulse will probably be quick and small at the moment of the arrest. Under any circumstances, however, in patients with a good circulation, the condition induced by an overdose is one of primary respiratory failure. The length of time the heart will hold out against such asphyxial symptoms will depend to a great extent upon its previous nutrition and strength. In the case of young and vigorous subjects experience shows that a comparatively long period of suspended breathing elapses before the heart's action becomes seriously depressed; whereas, in debilitated or flabby subjects, with dilated, fatty, or feeble hearts, any marked interference with respiration would much more quickly lead to final cardiac arrest.

Patients with any **pre-existing narrowing or abnormality of the upper air-passages** are particularly prone to pass into a state of dangerous asphyxia when nitrous oxide is pushed to its fullest extent. This is well exemplified by the fatal cases to which I have referred, and also by Illustrative Case, No. 37, p. 450, a case in which I was obliged to perform tracheotomy in order to resuscitate the patient. Elderly, obese subjects are liable to pass into a state of completely obstructed breathing, by reason of the engorged tongue being spasmodically drawn towards the pharyngeal wall. Patients with enlarged tonsils, adenoid growths, etc., are similarly liable to arrested breathing. The numerous other conditions capable of favouring primary respiratory failure are elsewhere fully considered (p. 443 *et seq.*).

The passage of foreign bodies into the larynx, trachea, or bronchi during nitrous oxide anæsthesia may set up asphyxial symptoms of a grave or fatal character (see p. 452).

(2) **Primary Circulatory Depression or Failure.**—There is every reason to believe that in moderately healthy subjects nitrous oxide is incapable of producing symptoms of circulatory depression except as a sequel to respiratory embarrassment. For close upon 20 years I have kept careful notes of every interesting or abnormal case of anæsthesia, and, on looking through my notes, I am unable to find a single instance of primary pulse failure wholly dependent upon the action of this gas.

It has been alleged that there is a grave risk of cardiac syncope from the performance of surgical operations, and particularly dental operations, upon patients imperfectly anæsthetised by nitrous oxide. But when we consider that hundreds, and possibly thousands, of persons are daily subjected to dental operations, whilst in the first and second degrees of anæsthesia, it is probable that the risk of syncope from this cause has been over-estimated. That reflex circulatory effects may arise when patients are emerging from nitrous oxide anæsthesia and the operation is still in progress, in other words, that patients may become "faint" from the distinct or indistinct perception of pain, is certain; that similar effects may manifest themselves even when consciousness is wholly abolished is quite possible; but that a fatal issue is thus prone to arise has not up to the present been proved. In nearly every recorded nitrous oxide death some disturbance of breathing would appear to have been present; and it is in the highest degree probable that, in many of the dangerous and fatal cases in which the symptoms have been regarded as primarily cardiac or circulatory, some undetected asphyxial factor was present.

(3) **Simultaneous Depression, or Failure of Respiration and Circulation.**—This condition is fortunately very rare. It is most likely to arise in patients with valvular or other forms of cardiac disease. Instead of the circulation being well maintained up to the point at which anoxæmic spasm or stertor arises, the pulse becomes feeble or imperceptible, a bluish pallor is observed, and the respiration, instead of being

stertorous or jerky, is markedly shallow. There is apparently a direct relation between the feeble circulation and feeble breathing. Given that the general circulation is satisfactory, the anoxæmic state induced by nitrous oxide leads to excessive rather than to diminished discharges from the respiratory centre. But when, from any particular cause, such as the presence of valvular or other cardiac disease, the cerebral circulation becomes defective, the respiratory centre appears to be more affected by the deficiency than by the quality of the blood which reaches it, and it hence happens that the breathing becomes shallow, without stertor or spasm. I have never seen this condition become so grave as to threaten life; although it is quite obvious that it might do so. In Case 15, Class A of the above group, the patient was the subject of an adherent pericardium and old-standing pleurisy—two conditions which would certainly render the administration of nitrous oxide somewhat hazardous. In this particular case, I am informed on good authority that death occurred without any indications of obstruction.

Post-mortem Appearances.—The post-mortem appearances of death from nitrous oxide will naturally depend upon the presence or absence of pathological conditions during life and upon the precise mode of death.

In 7 of the cases included in Class A in the above list post-mortem records are available. Speaking generally, these records point to death by asphyxia. As a good example of the usual appearances, those found in Case 2 may be studied.[1] The cerebral membranes were distended with serous fluid, the cerebral veins intensely congested, and the cerebral ventricles full of fluid; the lungs were very dark and intensely congested; the right side of the heart was full of dark fluid blood and the left side empty. In Case 3 each ventricle contained a little blood; the auricles were empty; and there was pulmonary and renal congestion. In Case 8 the right side of the heart was full of dark fluid blood; the heart substance was flabby and fatty; the lungs, brain, and kidneys were congested. In Case 9 the ventricles were firmly contracted; there was a dark clot in the mitral valve; the lungs and spleen were congested. In Case 10 all cavities of the heart were empty, except for a small quantity of fluid blood in the right ventricle; the veins of the chest were all full of dark fluid blood; the lungs were engorged and nearly airless; and there was venous engorgement of the cerebral hemi-

[1] *Lancet*, vol. i., 1877, p. 544.

spheres. In Case 15 there were considerable **pericardial adhesions**; the heart had undergone slight fatty degeneration; and the left pleural cavity was obliterated by adhesions. In addition to the details here given, there were in many of the cases certain pathological states, such as enlargement of tonsils, catarrhal and œdematous conditions in different parts of the air-passages, enlargement of bronchial glands, etc. These states, however, are of interest as *predisposing* causes of the asphyxial seizure.

It must be borne in mind in considering post-mortem appearances (1) that differences in the method of performing autopsies may of themselves introduce differences in the appearances observed; and (2) that artificial respiration, inversion, and other movements to which the body may have been subjected immediately after death, may alter the conditions of the great vessels, heart cavities, and lungs, more particularly as regards the quantities of blood contained within these parts at the actual moment of dissolution.

G. AFTER-EFFECTS

For reasons which have already been given, the administration of pure nitrous oxide is necessarily exceedingly short, and it hence happens that disagreeable after-effects are generally completely absent. The intercurrent asphyxial phenomena, by limiting the intake of the anæsthetic, not only prevent a prolonged administration, but a deep form of anæsthesia. **Transient giddiness or headache** occasionally occur; and **lassitude or sleepiness** may be experienced. Although the presence of undigested food within the stomach is not nearly so likely to lead to **vomiting** as when ether or chloroform has been employed, it is nevertheless important that attention should be paid to the diet (see p. 188). Some patients invariably suffer from **nausea** or even actual vomiting after nitrous oxide; but such cases are very exceptional. So-called "bad travellers" are often thus affected. A double administration of the gas with an interval of consciousness is prone to lead to after-sickness, especially in dental practice. When re-breathing has been practised, recovery will not take place quite so rapidly as usual, and headache and nausea may be thus initiated. Headache unattended by nausea sometimes follows the administration when food is present in

the stomach. Should blood be swallowed during or after the operation, after-sickness will be likely to follow.

Feelings of faintness are, as a general rule, dependent upon some gastric disturbance brought about by the administration. Such feelings are, as will be gathered from what has just been said, most common when the diet has not been properly regulated.

Hysterical outbursts, or transient states of hallucination and struggling, are sometimes met with after the administration of nitrous oxide, but are very exceptional.

Protracted stupor, cataleptic states, hemiplegia,[1] and even **insanity**[2] have one and all followed the administration of nitrous oxide; but such sequelæ are exceedingly rare.

Temporary glycosuria and even true **diabetes**[3] are also said to have been produced by the inhalation of nitrous oxide; but the evidence in favour of such charges cannot be regarded as conclusive.

Retinal hæmorrhage, from intense venous engorgement, has been known to occur under the influence of pure nitrous oxide.[4]

Section II.—The Administration of Definite Mixtures of Nitrous Oxide and Air

A careful study of the phenomena resulting from the administration of nitrous oxide with definite proportions of atmospheric air is obviously essential before we can discuss the

[1] A curious case is reported by Dr. Ashford (*Amer. Journ. Med. Scien.* New Series, vol. lvii., 1869, p. 408). A girl of sixteen became insensible for two hours after the exhibition of nitrous oxide. Headache, dizziness, and left hemiplegia followed. Dr. H. C. Wood also refers to another case (*Brit. Med. Journ.*, 16th Aug. 1890, p. 385), which occurred in Philadelphia: "A gentleman arose from the dentist's chair after an inhalation of nitrous oxide, staggered, and fell in an apoplexy."

[2] See an interesting paper by Dr. Savage, "Insanity following the Use of Anæsthetics in Operations" (*Brit. Med. Journ.*, 3rd Dec. 1887, p. 1199), in which is mentioned the case of a young woman, a chronic alcoholic, and liable to hysterical attacks, who, after the extraction of teeth under nitrous oxide gas, was attacked by delirious mania, which lasted for three weeks and terminated in dementia. Dr. Savage regards the anæsthetic as the immediate cause of the attack.

[3] See *Brit. Med. Journ.*, 16th August 1890, p. 385.

[4] Mr. J. Tweedy informs me that he has seen a case of this kind. The hæmorrhage was extensive and "about the posterior pole of the fundus."

use of this anæsthetic with unknown proportions of air. therefore propose, in this section, to give a brief summary o the results which I obtained in the course of the investigati referred to on p. 222. As will be pointed out in the followin section, it has been customary, ever since the anæstheti properties of nitrous oxide became generally recognised, t administer this agent in conjunction with atmospheric ai more particularly with the object of maintaining insensibilit for prolonged surgical operations; but, so far as I am aware no cases have been recorded in which definite mixtures o nitrous oxide and air have been administered.

I employed in the investigation a specially made gasomete by which I could administer any desired percentages of nitrou oxide and air. The following administrations were conducted carefully timed, and recorded :—

				Cases.
Nitrous	oxide with	3	per cent air	5
,,	,,	5	,,	10
,,	,,	6	,,	6
,,	,,	7	,,	6
,,	,,	10	,,	10
,,	,,	12	,,	5
,,	,,	14	,,	4
,,	,,	15	,,	9
,,	,,	16	,,	5
,,	,,	18	,,	12
,,	,,	20	,,	7
,,	,,	22	,,	14
,,	,,	25	,,	8
,,	,,	30	,,	4
,,	,,	$33\frac{1}{3}$	,,	1
				106

Great care was exercised in conducting each administratio in precisely the same manner, and records were made as to (1) *the duration of inhalation necessary for the production of anæsthesia for a short dental operation*; (2) *the average duration of anæsthesia after inhalation*; (3) *the average quantity of th mixture used*; (4) *the degree of anoxæmic convulsion (jactitation)*; (5) *alterations in the colour of the features*; (6) *stertor*; (7) *phonation*; (8) *reflex and excitement movements*; and (9) *after-effects*.

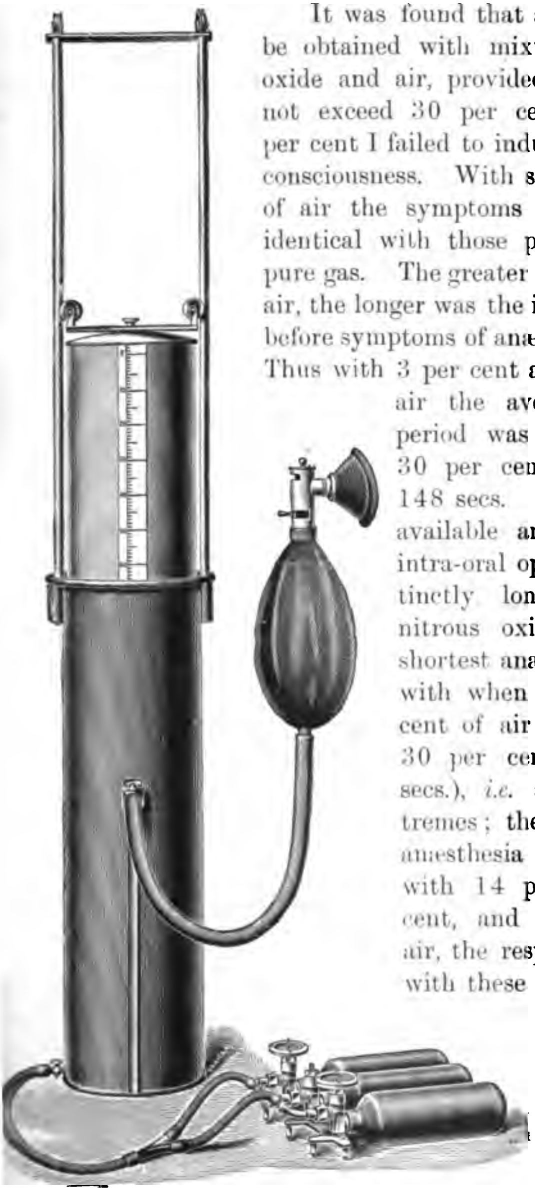


FIG. 19.—Specially constructed Gasometer by which definite mixtures of Nitrous Oxide and Air and of Nitrous Oxide and Oxygen were administered.

It was found that anæsthesia could be obtained with mixtures of nitrous oxide and air, provided the latter did not exceed 30 per cent. With $33\frac{1}{3}$ per cent I failed to induce complete unconsciousness. With small percentages of air the symptoms were practically identical with those produced by the pure gas. The greater the proportion of air, the longer was the inhalation period before symptoms of anæsthesia appeared. Thus with 3 per cent and 5 per cent of air the average inhalation period was 69 secs.; with 30 per cent of air it was 148 secs. The duration of available anæsthesia for an intra-oral operation was distinctly longer than after nitrous oxide alone. The shortest anæsthesia was met with when employing 3 per cent of air (30·8 secs.) and 30 per cent of air (29·7 secs.), *i.e.* at the two extremes; the longest average anæsthesia being recorded with 14 per cent, 16 per cent, and 22 per cent of air, the respective durations with these percentages being 40·5 secs., 42 secs., and 42·6 secs. It is an interesting fact that there was more anoxæmic convulsion with 3 and 5 per

cent of air than with pure nitrous oxide, the explanation being that, in the absence of all oxygen, obstructive stertor comes about so quickly as to cut short the intake of the anæsthetic gas before the blood has become sufficiently altered to induce any marked convulsive seizure. With higher percentages of air the anoxæmic muscular phenomena progressively lessened, disappearing altogether with 30 per cent of air. With moderate percentages of air the clonic movements were but feebly marked. Lividity and cyanosis were, like anoxæmic convulsions, more evident with small percentages of air than with pure nitrous oxide, and for the same reason. With 30 per cent of air there was but little alteration in the normal colour. The tendency to stertor progressively lessened as the percentages of air rose. With mixtures poor in air the stertor was coarser and more irregular than with those containing moderate percentages. Very interesting changes in the type of stertor were observed as the percentages of air increased. There was somewhat less phonation during dental operations performed under nitrous oxide mixed with small percentages of air than under nitrous oxide itself; but with mixtures containing more than 10 per cent of air phonation was common. Reflex and excitement movements were, on the whole, less marked than with pure nitrous oxide; and this was especially noticeable with moderate percentages, for with such percentages the best types of anæsthesia were attainable. So far as the general results of these cases are concerned, the investigation showed that with percentages of air between 14 and 22 a very distinct improvement was manifest over the ordinary nitrous oxide cases. With percentages below 14 and above 22 the improvement in general results was less marked. The conclusion at which I arrived in the course of this investigation was that the best definite mixture for men was one containing from 14 to 18 per cent of air, whilst the best for women and children was one containing from 18 to 22 per cent of air.

I am not aware that administrations of nitrous oxide and air, thus accurately mixed, have been conducted upon any large scale in our hospitals; but it seems to me that it would be worth while to employ such mixtures in preference to pure

itrous oxide. The chief drawback of the system undoubtedly the necessity for large gasometers.

SECTION III.—THE ADMINISTRATION OF NITROUS OXIDE WITH INDEFINITE QUANTITIES OF AIR

The effects produced by administering nitrous oxide with ndefinite quantities of air will necessarily depend upon umerous circumstances. The most important of these is the roportions existing between the various gases inhaled. Putting n one side for the moment all plans of administration in hich re-breathing is possible, and taking it for granted that he gases presented to the lungs are inspired and expired hrough accurately working valves and through orifices of ufficiently large calibre, it may be said that, strictly speaking, here are two distinct systems by which nitrous oxide may be dministered with indefinite quantities of air. In the first of hese the anæsthetist administers the pure gas as already escribed, till his patient is partially or completely anæsthetised; e then admits one or more breaths of air by turning the topcock; and he continues to thus alternately administer itrous oxide and air till (as in general surgery) the operation s completed, or till (as in oral or nasal surgery) sufficiently leep anæsthesia has been induced. In the second system f conducting the administration the anæsthetist aims at dministering nitrous oxide and air concurrently rather han alternately, and with this object he employs some imple expedient or contrivance which will, from the commencement to the end of the administration, allow of sufficient air gaining access to the lungs to obviate any marked sphyxiation from the nitrous oxide. In actual practice hese systems are often combined or used indiscriminately —the patient at one moment breathing pure nitrous oxide, t another nitrous oxide mixed with air, and at another air tself.

Should to-and-fro breathing be permitted during any part of a gas-and-air administration, a more complex result than

that obtainable when accurately working valves are present will necessarily ensue, for instead of the excreted carbonic acid escaping as it would under ordinary circumstances, it is intercepted, so to speak, in the inhaling bag, and its quantity will progressively increase within that bag so long as to-and-fro breathing is permitted. Moreover, the quantity of this respiratory product present in the bag at any given moment will depend upon the extent to which air has been admitted with the nitrous oxide (see p. 217).

From time to time during the last thirty years, and particularly in the United States, cases have been recorded in which general surgical operations, varying in duration from a few minutes to an hour or longer, have been performed under nitrous oxide administered in one or other of the ways above described; and in this country Clover and others have chronicled similar results. The first systematic endeavour to administer nitrous oxide and air *concurrently* appears to have been made by Dr. George Brush of Brooklyn,[1] who employed an apparatus with a sliding valve which could be so arranged as to admit atmospheric air according to the needs of the patient. Operations lasting upwards of an hour were performed under the influence of anæsthesia thus induced. But there is little to be said in favour of such a line of practice, save perhaps for very exceptional cases; for the resulting anæsthesia is liable to be uneven and unsatisfactory in its type, owing to the physical characters and peculiar physiological action of this anæsthetic—in other words, to the rapidity with which the patient passes from the extreme of anæsthesia and asphyxia to that of intoxication and recovery. Had we no better means at our disposal for inducing and maintaining anæsthesia, we should have to be content with the results thus obtainable. But as compared with the anæsthesia of ether or chloroform that which thus results from the inhalation of pure nitrous oxide and air cannot be regarded with favour. At the same time there are undoubtedly certain special cases in which the use of this system is distinctly advantageous. For example, when an anæsthesia of

[1] *Brooklyn Med. Journ.*, May 1890.

from one to five or ten minutes is needed, when absolute immobility and complete muscular relaxation are not essential, and when there is some special reason for avoiding ether or chloroform, this plan of anæsthetisation may be employed. It certainly has the great merit that it is rarely followed by after-effects; but it cannot be recommended when deep anæsthesia, in our modern sense, is essential to success; nor can it be regarded as appropriate for all types of subjects. As already pointed out, there are numerous patients in whom the asphyxial condition incidental to many methods of anæsthetising must be studiously avoided, and although it is theoretically possible to obtain a non-asphyxial anæsthesia by this system, such an anæsthesia is not always obtainable. In conducting the administration of nitrous oxide and air for an ordinary surgical operation, the anæsthetist may either adopt the *alternate* plan, or, by keeping the air-hole of the stopcock slightly open, he may *concurrently* administer the nitrous oxide and air. The longer the administration has proceeded, the larger may be the quantity of air allowed. By carefully watching the patient's symptoms, the precise junctures at which the change from nitrous oxide to air should be effected, or at which more air should be allowed, will be readily ascertained. An endeavour must be made to maintain a snoring, regular breathing, with moderate duskiness.

As nitrous oxide is unquestionably of special utility in dental surgery, it is not surprising that a great deal of attention has been directed towards improving the methods of administering this anæsthetic for the extraction of teeth. Not only have attempts been made to improve the *type* of anæsthesia, but many ingenious devices have been proposed for *prolonging* the insensibility ordinarily produced. Although, as will be presently shown, the best form of anæsthesia is attainable only when oxygen (and not atmospheric air) is mixed with the nitrous oxide, "gas-and-air" anæsthesia is distinctly preferable to that produced by nitrous oxide alone. This has been specially pointed out by Mr. George Rowell.[1] When

[1] See *Journ. Brit. Dent. Assoc.*, 15th October 1892, p. 669.

from ten to twenty breaths of the pure gas have been taken, Mr. Rowell admits one breath of air, and subsequently repeats this procedure about every fifth breath. A longer and better form of anæsthesia results than when pure nitrous oxide is continuously inhaled. In the majority of cases a commencing irregularity in breathing without either stertor or muscular twitching is the sign that proper anæsthesia has been induced.

With regard to the prolongation of anæsthesia for protracted dental operations, the first attempt appears to have been made by Clover and Coleman, who devised and used a nose-piece through which the administration of the gas might be kept up during the operation within the oral cavity. The next step in this direction was taken by Mr. S. Coxon,[1] who, after inducing anæsthesia in the ordinary way, places a metal tube in the mouth and keeps up a supply of "gas" during the operation. It is advisable, according to Dr. McCardie,[2] to close the anterior nares when employing a mouth-tube, and if this be done, anæsthesia of several minutes' duration may be obtained. Quite recently Mr. Alfred Coleman[3] has successfully revived the use of the nose-piece; and working upon Mr. Coleman's suggestions, Mr. Herbert Paterson[4] has obtained results which are certainly encouraging from many points of view.

By working the foot-key of a nitrous oxide cylinder,[5] the liberated gas is made to enter a small bag, to which is attached a two-way stopcock (Fig. 20). From this stopcock a couple of tubes pass to supply a metal nose-piece, fitted with a rubber air-pad to allow of accurate adaptation. The bag having been *nearly* filled with "gas," a mouth-prop is inserted, the nose-piece *carefully* adjusted, and the stopcock turned on. A stream of "gas" now passes into the nasal passages during each inhalation. The patient thus breathes nitrous oxide through the nose, and a variable amount of air through the mouth. As anæsthesia approaches, the breathing as a rule becomes entirely nasal, practically no air gaining access through the mouth. After the first few breaths it may be necessary to

[1] *Clinical Journal*, 1st June 1898, p. 116.
[2] *Ibid.*, 29th March 1899, p. 37.
[3] *Ibid.*, 25th May 1898, p. 92.
[4] *West London Medical Journal*, July 1899.
[5] I am indebted to Mr. Paterson for this description.

slightly distend the bag. The operation is commenced in about 40 seconds. The anæsthesia can be maintained as long as is desired, but it is necessary to turn off the stopcock about once in every four or five breaths, so as to allow the patient to obtain a breath of air through the aperture in the stopcock (H). Only the lightest degree of duskiness is necessary, stertor and cyanosis being avoided by giving sufficient air. In addition to the nose-piece, there is an independent celluloid mouth-piece fitted with one (expiratory) valve. This may be required when, as occasionally happens, there is difficulty in establishing nasal breathing, or it may be needed to shorten the period of induction. With the mouth-piece anæsthesia is obtained in 15 or 20 seconds. In the majority of cases its use is not required, and from the patient's point of view it is undesirable, as the administration is more pleasant without it. As regards the quantity of "gas" used, the method is economical. From 8 to 10 gallons of gas are required for an ordinary administration. Anæsthesia can be maintained for 10 minutes with from 25 to 30 gallons of gas.

FIG. 20.—Paterson's Apparatus for administering Nitrous Oxide for Prolonged Operations within or about the Mouth.

The results obtained by this and other methods of prolonging nitrous oxide anæsthesia for dental operations are, from the patient's point of view, remarkably satisfactory; for not only may an absolute immunity from pain be secured for three, four, or five minutes, or even longer, but disagreeable after-effects are rarely met with. The type of anæsthesia, however, can hardly be regarded as satisfactory in the modern sense; and in order that the best

results may be obtained, a third person—that is to say, some one in addition to the surgeon and the anæsthetist—is needed to steady the patient, insert and adjust the Mason's gag, and sponge out blood, etc. It is quite possible that in a short time certain improvements may render this system of anæsthetisation more successful than it is at present, and should this be so a great step will have been achieved.

Section IV.—The Administration, at Ordinary Atmospheric Pressures, of Definite Mixtures of Nitrous Oxide and Oxygen

From what has been said in the preceding sections of this chapter it is clearly possible, by the simple dilution of nitrous oxide with air, to more or less completely prevent lividity, tumultuous breathing, and jactitation, without interfering with anæsthesia. But there is one formidable objection to the use of air as an oxygenating agent, viz. that it contains such a large percentage of nitrogen. Although this latter gas, when given alone, will produce anæsthesia by excluding oxygen,[1] it cannot in any way contribute towards nitrous oxide anæsthesia in the presence of that percentage of oxygen which is capable of preventing cyanosis and clonic muscular spasm. If we administer with nitrous oxide a percentage of air which will prevent lividity and the other symptoms referred to, we shall, in most cases, also prevent deep anæsthesia, owing to the small percentage of nitrous oxide which would be possible in such a mixture. For example: a mixture of 40 per cent of air and 60 per cent of nitrous oxide would contain about 8 per cent of oxygen and about 32 per cent of nitrogen; and although the 8 per cent of oxygen would be sufficient to nearly or completely preserve the natural colour of the patient's face, and to suppress clonic muscular spasm, the 60 per cent of nitrous oxide would be insufficient to produce tranquil anæsthesia. If, however, instead of using air for oxygenating purposes, we employ oxygen, we shall be able to replace the 32 per cent of

[1] The reader is referred to pp. 382 and 383, where he will find details of several cases in which I administered nitrogen for tooth extraction.

useless nitrogen by a corresponding quantity of useful nitrous oxide, and the proportion of the latter will now rise to 92 per cent. With such a large percentage of nitrous oxide, anæsthesia is almost certain to become established, and the percentage of oxygen remaining the same as in the nitrous oxide-and-air mixture, cyanosis and other evidences of diminished blood oxygenation will be prevented. These few considerations will act as a link to connect the preceding with the present section.

As already mentioned (p. 208), Dr. E. Andrews of Chicago was the first to employ oxygen in conjunction with nitrous oxide, and to obtain a non-asphyxial form of anæsthesia by this means. It was not, however, till ten years later, when Paul Bert published his interesting observations, that this system of anæsthetisation began to attract attention. Bert's researches led him to regard nitrous oxide as an agent which, as customarily given, could only produce anæsthesia when administered pure, *i.e.* free from air or oxygen. He came to the conclusion that, whilst it was desirable to avoid all asphyxial phenomena by mixing oxygen with nitrous oxide, it was impossible to produce anæsthesia by such a mixture without increasing the atmospheric pressure (see p. 248). But in spite of Bert's views it soon became clear from the observations of Klikowitsch,[1] Winckel, Döderlein, Zweifel, Hillischer, and the author that such an increase, although it was doubtless capable of intensifying the effects, was not absolutely necessary for the production of anæsthesia.

Before proceeding to the consideration of Bert's results (Section V.), and to the description of the best means for producing non-asphyxial nitrous oxide anæsthesia at ordinary pressures (Section VI.), I propose to give a brief summary of the results at which I arrived when administering various definite mixtures of nitrous oxide and oxygen.

In the course of my investigation[2] I conducted the following administrations:—

[1] For references to the works of these observers, see my book on *The Administration of Nitrous Oxide and Oxygen for Dental Operations*, p. 10.

[2] See footnote, p. 222.

					Cases.
Nitrous oxide	with	3	per cent	of oxygen	5
"	"	4	"	"	10
"	"	5	"	"	17
"	"	6	"	"	11
"	"	7	"	"	11
"	"	8	"	"	18
"	"	9	"	"	5
"	"	10	"	"	10
"	"	11	"	"	7
"	"	13	"	"	2
"	"	20	"	"	4
					100

As in the air cases, these mixtures were accurately prepared and accurately administered under precisely similar circumstances, by means of an apparatus with accurately working valves, great care being taken to exclude the minutest proportions of atmospheric air. Records were taken with regard to the various points referred to on p. 236. The duration of inhalation necessary for the performance of a dental operation increased as the percentage of oxygen rose, that is to say, a shorter inhalation was necessary with small percentages of oxygen than with large. For example, with 3 per cent of oxygen the average inhalation period was 96·6 seconds: whereas with 20 per cent of oxygen it was 223·5 seconds. There was a very marked contrast between the short inhalation period of pure nitrous oxide (55·9 seconds) and that of mixtures of nitrous oxide and oxygen. It is interesting to note that deep anæsthesia was obtainable even when the proportion of oxygen was as great as that in atmospheric air. With regard to the duration of anæsthesia after inhalation, this was distinctly longer than when mixtures of nitrous oxide and air were employed, just as the anæsthesia with these latter mixtures was greater than when pure nitrous oxide was used. Thus, the lowest average anæsthesia (39·7) was very little below the highest (42·6) of the air cases. The best results, so far as a lengthy available anæsthesia is concerned, were met with when using 7 per cent of oxygen, the average duration of anæsthesia after inhaling nitrous oxide mixed with this percentage of oxygen being 50·1 seconds. A very interesting result of the investigation was to show that anoxæmic convulsions were

readily prevented, even by small percentages of oxygen. During the inhalation of nitrous oxide, either pure or with oxygen up to 4 per cent, some degree of anoxæmic convulsion is very common. But when once 5 per cent of oxygen is reached, very little convulsive movement is observed, and with 6 per cent and over there is no such movement visible. The anoxæmic convulsion of pure nitrous oxide becomes progressively attenuated and weakened, so to speak, as the proportion of oxygen mixed with the anæsthetic gas increases. With regard to alterations in the patient's colour, I found that with less than 11 per cent of oxygen some degree of lividity was present; but with this percentage and over, the normal colour was retained. With 8, 9, and 10 per cent of oxygen the alteration was very slight. With smaller percentages the lividity was of course greater. The effects of even small percentages of oxygen in preventing stertor were very marked. Thus, with 3, 4, and 5 per cent of oxygen the ordinary stertor of pure nitrous oxide loses its irregular character, and becomes replaced by a regular snoring sound, similar in its type to that of ether or chloroform. With somewhat higher percentages of oxygen, snoring becomes less pronounced. With 20 per cent of oxygen the snoring altogether vanishes. Phonated sounds are far less common under nitrous oxide and oxygen than under nitrous oxide and air. They are most likely to arise with very small or with very large percentages. Reflex and excitement movements are uncommon with small percentages of oxygen; but are likely to assert themselves, and possibly to become inconvenient, when the percentage of oxygen rises to 10 per cent or more. Stamping, kicking, side-to-side movements, etc., are very common with from 10 to 20 per cent of oxygen. As regards the general result: the best mixtures for adult males were those containing 5, 6, or 7 per cent of oxygen; and mixtures containing 7, 8, or 9 per cent were best for females and children.

The chief drawbacks to the use of definite mixtures of nitrous oxide and oxygen are—(1) that they are difficult to prepare with accuracy and in sufficient quantities; (2) that different subjects require different percentages; and (3) that

the proportion of oxygen cannot be increased or decreased to meet special conditions arising during the administration. At the same time it is interesting to know the phenomena which are associated with different percentages; for it is only upon a basis of this kind that we can successfully administer nitrous oxide and oxygen for protracted operations (see p. 255).

Section V.—The Administration, under increased Atmospheric Pressures, of definite Mixtures of Nitrous Oxide and Oxygen (Paul Bert's Method)

The following extract from the writings of Paul Bert will express the views which he held[1]:—

My experiments have demonstrated that, in an animal breathing pure nitrous oxide, when anæsthesia is established, 100 volumes of arterial blood contain 45 volumes of nitrous oxide. If, then, we introduce into the blood 45 volumes of nitrous oxide for every 100 volumes of blood, we shall obtain anæsthesia. Now, when pure nitrous oxide is contained in a bag under ordinary pressure this gas is at the tension of 100. But if the bag of gas is placed in an air-tight chamber, the pressure in which is raised to two atmospheres, the tension of the gas in the bag will be 200. And if this bag within the air-tight chamber, instead of containing 100 per cent of nitrous oxide, viz. this gas in a state of perfect purity, contain only 50 per cent, the tension of this 50 per cent of nitrous oxide will be equal to 100, that is to say, the quantity of nitrous oxide will be exactly that which is necessary to induce anæsthesia. The other 50 per cent can therefore be occupied by another gas for sustaining life, viz. oxygen, and it will therefore be possible to carry out prolonged operations. I have chosen these figures to render the explanation of the method at which I have aimed more intelligible. But they must not be considered as indicating the proportions of the oxygen and nitrous oxide to be employed. The proportion of oxygen would be too high,—in fact, we know that air contains only 21 per cent. The problem therefore resolves itself into a very simple calculation. By mixing 85 parts of nitrous oxide with 15 parts of oxygen it is only necessary to raise the pressure to 89·5 cm. Supposing the barometrical pressure to be 76 cm., an extra pressure of only 13·5 cm. of mercury is required to induce anæsthesia. Under these conditions the animal operated upon soon falls asleep and into deep anæsthesia. The circulation and respiration are in no way influenced by the nitrous oxide, though the perceptive faculties are suspended, and if the quantity of the gaseous mixture inhaled by the animal is sufficient, it is possible to maintain the most absolute anæsthesia for several hours.

[1] *Progrès Médical*, No. 9, 1880. See also *Traité d'Anesthésie Chirurgicale*, by J. B. Rottenstein, Paris, 1880, p. 303.

After a series of satisfactory experiments upon lower animals, Bert put his theory to a practical test. He had constructed for him a metal chamber in which the atmospheric pressure could be raised to the desired extent. The chamber was large enough to contain several persons. A mixture of 85 per cent of nitrous oxide and 15 per cent of oxygen was administered to a patient, and an extra pressure of 13·5 cm. (*i.e.* a total pressure of 89·5 cm.) was employed. The first operation during nitrous oxide and oxygen anæsthesia under pressure was performed by M. Léon Labbé on 15th February 1879. An in-growing toe-nail was painlessly removed during tranquil anæsthesia free from all traces of asphyxia. On 20th March 1879, M. Péan amputated a leg with equal success. Numerous other operations were performed. In the large majority of cases anæsthesia is said to have been of the most perfect type. There was no alteration of colour, the breathing was tranquil, and the pulse good and regular. In a few cases, however, excitement and nausea were noted.

The accompanying drawing shows a chamber which M. Claude Martin of Lyons has used successfully.[1] The following are its chief parts:—A. Air-tight metal chamber with windows. B. Sliding doors. C. Arrangement for introducing anything into chamber without lowering internal pressure. D. Canvas bag for holding the mixed gases. E. Tap through which the mixture passes to inhaling apparatus. F. Receiver containing mixed gases under greater pressure than that inside chamber. GG. Taps through which the mixed gases pass to the bag inside the chamber. H. Intermediate receiver for compressed air charged prior to the administration through the tap K. By using this intermediate receiver the compressed air which has been warmed by the action of the pumps is allowed to cool, and can be transmitted to the chamber when required through the taps II. J. Tap for lowering pressure in chamber, should occasion require. M. Martin found that he obtained best results when working with percentages and pressures somewhat different from those advocated by Paul Bert. He uses 88 per cent of nitrous oxide with 12 per cent of oxygen, and maintains an atmospheric pressure within the chamber of 110 cm. With the percentages and pressure recommended by Paul Bert he met with considerable excitement, which led him to modify the details of the method.

---

1 M. Martin has very kindly given me permission to reproduce this drawing. The reader will find much interesting information in M. Martin's pamphlet, *De l'Anesthésie par le Protoxyde d'Azote avec ou sans tension*, 1883.

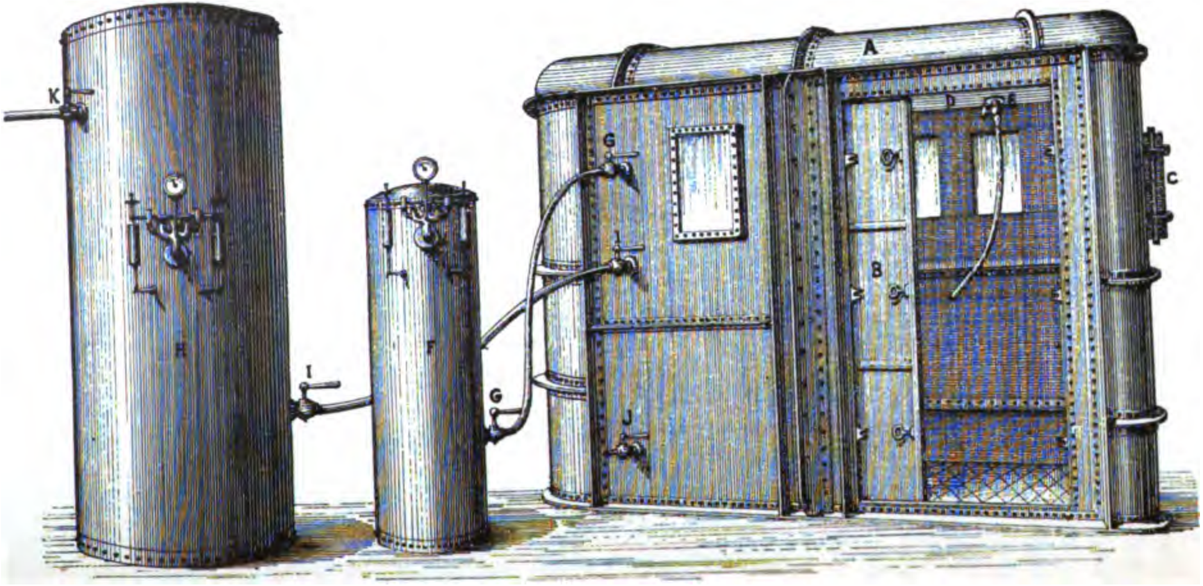


Fig. 21.—Air-tight-Chamber for the Administration of Nitrous Oxide with Oxygen under an increased Atmospheric Pressure (Paul Bert's Method).

It is unnecessary to further describe Paul Bert's method. The apparatus is, as will be gathered from the drawing, too complicated, too costly, and too cumbrous to allow of its being widely used. I am informed, too, on good authority, that the increased pressure within the chamber not unfrequently produces considerable discomfort to those engaged in the operation.

The question naturally arises: Is the anæsthesia thus obtained more satisfactory in its type than that which can be secured by administering these two gases together, in proper proportions, at ordinary atmospheric pressures, and by varying the percentage of oxygen to meet the special circumstances of each case? That an increase in atmospheric pressure is serviceable in preventing or treating excitement has been proved by those who have employed Bert's method—notably by Dr. C. Martin of Lyons; but, until further experiments have been made, it is difficult to say whether, at ordinary atmospheric pressures, such excitement cannot equally well be avoided or allayed by decreasing the proportion of oxygen in the mixture.

Section VI.—The Administration, at Ordinary Atmospheric Pressures, of Nitrous Oxide with Varying Proportions of Oxygen

The first successful attempt to administer nitrous oxide and oxygen at ordinary atmospheric pressures by means of an apparatus capable of regulating the proportions of the two gases was made by Hillischer[1] of Vienna; and it was the report of his work that first directed my attention to the subject. In 1886 I commenced a series of experimental administrations at the Dental Hospital of London; I tried a large number of different methods of procedure[2]; and I carefully tested Hillischer's apparatus. I found that by Hillischer's method it was impossible to finely adjust the

[1] See a pamphlet by Dr. Hillischer, *Schlafgas*.

[2] In a paper which I read at the Odontological Society (*Trans. Odont. Soc.*, June 1892) I described in detail the various methods which I tried.

oxygen supply; that the channels through the apparatus were too narrow to allow of free respiration; that the administrator required the services of an assistant in order to keep the gas-bags properly filled; and that the apparatus was not sufficiently portable to fit it for the requirements of English practice. I therefore devised an apparatus which was free from these objections; and as it has for many years fulfilled its requirements to my satisfaction, I propose to devote the remainder of this section to describing its action and the type of anæsthesia which it is capable of producing.

The Author's Method of Administration

A. APPARATUS

Two cylinders of liquefied nitrous oxide and one of compressed oxygen are needed. The stand which I use is shown in Fig. 22. It is constructed with the object of being as portable as possible, the oxygen cylinder being placed above two nitrous oxide cylinders. When the nitrous oxide is released by working the foot-key, it passes into the

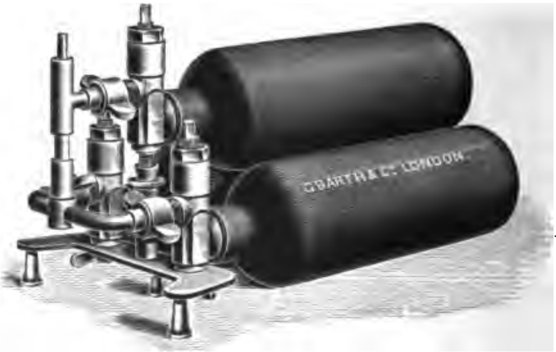


Fig. 22.—The author's Stand and Union for the Nitrous Oxide and Oxygen Cylinders.

vertical brass tube of large calibre at the extreme left of the wood-cut. When the oxygen is released it passes into the vertical brass tube of smaller calibre which is seen to be emerging from the centre of the nitrous oxide tube. To these two brass exit tubes, one inside the other, two corresponding rubber tubes are attached for the transmission of the respective gases to the double bag shown in Fig. 23. It will be seen that the first few inches of the nitrous oxide transmission tube are surrounded

by spiral wire to prevent kinking. When the two tubes approach the double bag they are made to pass independently by means of a Y piece to supply this double bag with the two gases. For general surgical cases it is advisable to have a specially large double bag. To the double bag the regulating stopcock is attached. The latter is shown in detail in Fig. 24. NOT is the nitrous oxide tube with its removable inspiratory valve, *iv'*. This is the tube to which the nitrous oxide half of the double bag is attached. OT and *iv* are the oxygen tube with its inspiratory valve. Nitrous oxide passes along NOT and through the large orifice NOO to the mixing chamber in which revolves the inner drum ID with its large slot S. The handle has an indicator which may be turned to various points on the flange shown in the woodcut. The oxygen which passes along OT enters the little oxygen chamber OC, from which it passes to the mixing-

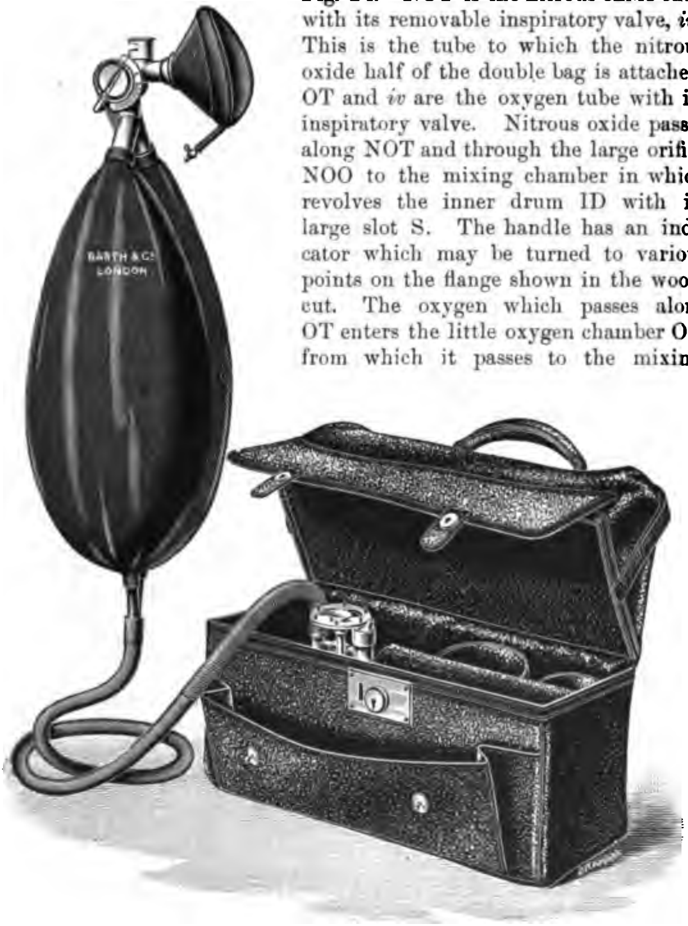


FIG. 23.—The author's Apparatus for administering Nitrous Oxide and Oxygen.

chamber through the 10 small orifices OO, any number of which may be opened by moving the inner drum. All the 10 oxygen orifices are of the same size except the first, and by means of the supplementary stopcock SS, this can either be made of the same size as the other 9 (first position of SS), or it can be made equal to the 10 orifices collectively

(second position of SS), or to 20 such orifices (third position of SS. From the mixing-chamber the gases are inhaled through the main inspiratory valve IV, expiration escaping at the expiratory valve EV. PD is a partial diaphragm which serves to direct the expirations upwards towards EV. When the inner drum is in position, and the indicator points to "AIR," air enters the stopcock at AH, and is breathed through IV and EV, the nitrous oxide and oxygen both being shut off. As the handle H is raised, the indicator passes from "AIR" to "N_2O," and pure nitrous oxide is breathed, because AH and OO are closed and NOO is open. If the handle H be still further raised, the indicator passes to "1," which means that whilst the nitrous oxide orifice NOO is still open, and the patient is breathing nitrous oxide, the first of the 10 oxygen orifices is also open, and oxygen gains admission with the nitrous oxide to the air-passages. At the commencement of the administration SS is turned so that the first oxygen orifice is the size of the rest, so that when the indicator points to "1," only a small percentage of oxygen, 1 per cent or less, is breathed. By moving the indicator to "2," "3," etc., any number of the 10 oxygen orifices may be opened, and a corresponding number of small streams of oxygen added to the nitrous oxide. If more oxygen be required than can pass through with the indicator at "10," the supplementary stopcock SS may be turned to its second position (= ten extra holes) and the indicator brought back to "2," when an amount of oxygen corresponding to that which would pass through twelve holes will be inhaled. If the indicator be made to pass to "3," whilst SS is in its second position, thirteen holes will be opened; and so on. If larger quantities of oxygen be needed, SS may be turned to its third position (= twenty extra holes). By this arrangement the administrator has at his disposal, so to speak, 30 oxygen orifices. The precise percentages of oxygen coming through these orifices will depend upon

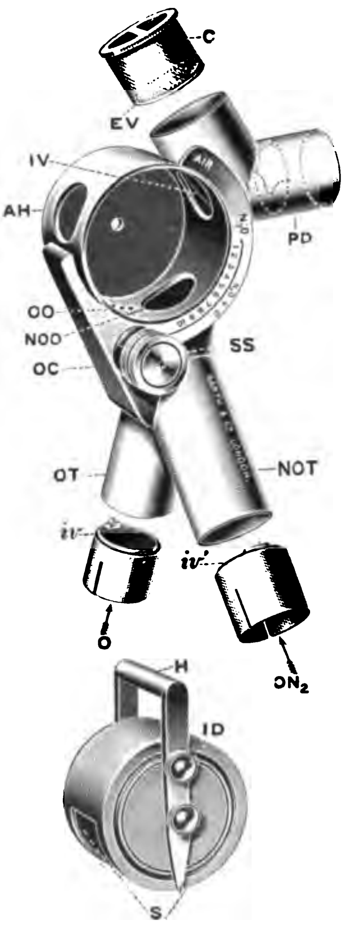


FIG. 24.—The Regulating Stopcock and Mixing-chamber shown in detail.

numerous circumstances, and the numbers given do not represent percentages. It is not necessary that the precise percentages of oxygen should be known. Each apparatus will be found to have its own particular characters, and these characters will always repeat themselves under the same circumstances. One apparatus may let through more oxygen than another; but the proportions can be easily graduated. It is very important that the rubber bags and all valves should be kept in good order. The valves require to be renewed occasionally.

B. THE ADMINISTRATION

In order to obtain good results, careful attention must be paid to several points.

In the first place, the type of subject must be considered. Just as with ether or with chloroform it is impossible to produce the best results on all occasions, so it is impossible in the case of nitrous oxide thus administered. The best subjects for this system are middle-aged and elderly women. Weakly middle-aged men are also good subjects, unless possessing so much hair about the face as to make it difficult to obtain a proper fitting of the face-piece. Robust, plethoric, obese, alcoholic, and excitable patients are not so satisfactory. Boys and girls, especially if florid, may secrete much mucus and saliva and display a tendency to retching and vomiting. Young women are favourable subjects as a general rule. Young men often give trouble by reason of muscular spasm. Patients with adenoid growths, enlarged tonsils, and allied conditions are prone to develop asphyxial symptoms unless considerable percentages of oxygen be given. Alcoholic subjects display a great tendency towards "jactitation," and are very susceptible to the deprivation of oxygen, so that the best results are to be obtained by the prolonged administration of a mixture comparatively rich in oxygen.

In the second place, the posture of the patient must receive attention. Should the patient be sitting, the head should not be extended, otherwise difficulties will be certain to arise. In general surgery, when it is necessary that the patient should be recumbent, a narrow operating table or flat couch should be employed. It is practically impossible to administer nitrous oxide and oxygen satisfactorily when a patient

is lying in the middle of a wide bed. It must be borne in mind that this form of anæsthesia is, as compared to that of ether or chloroform, distinctly lighter in character, and that reflex movement, especially in certain types of subjects, cannot always be prevented. This is particularly the case in operations about the feet and legs. If the patient display any evidences of nasal obstruction a small mouth-prop should be inserted between the teeth.

In the third place, the anæsthetist should make sure that he has a sufficient supply of the two gases, and that his apparatus is in perfect working order.

The bags should not be charged until immediately before the administration, and they should then be half filled with their respective gases. The face-piece should be carefully chosen, for a want of co-aptation which in the case of pure nitrous oxide might not be detrimental, would, in the case of the mixture, be likely to lead to partial or complete failure. When the face-piece is applied, air will be breathed freely through the apparatus, and the sound of the acting valves will prove that the face-piece fits well. The patient should be instructed to breathe freely and moderately deeply, "in and out through the mouth." This is important, for as he commences to breathe, so he will probably continue when the mixture is admitted. When the administrator sees and hears that breathing is free, and not till then, he should turn the indicator to "2." Nitrous oxide with a small percentage of oxygen will thus gain admission to the lungs. It is best to commence with a comparatively small percentage of oxygen, as we have to allow for that originally present in the lungs and blood. If we begin with, say, 10 per cent, excitement will be liable to arise. The objection to giving pure nitrous oxide itself at the beginning, is that it is sometimes difficult to quickly neutralise the effects thus produced without going to the other extreme and administering too much oxygen. After two or three seconds the oxygen indicator may be turned to "3," and in a few seconds more to "4." In children, anæmic subjects, and debilitated persons, the indicator may be moved to "3" and "4" more quickly than in strongly-built individuals. During these manipulations the two bags must be

kept as nearly as possible equal in size. It is rarely, if ever, necessary to replenish the oxygen bag during the administration for a dental operation, but the foot must be constantly kept working the nitrous oxide key. In general surgery, when a more or less protracted administration is called for, fresh oxygen must be admitted to the bag from time to time. Considerable practice is necessary to keep both bags equal in size and partially distended throughout. Should phonation, laughter, excited movement, or struggling assert itself, the administrator must not increase the oxygen percentage for the present, or must even give less of this gas, by turning back the indicator for a few breaths. In 40 or 50 seconds from the commencement of the inhalation the indicator may usually be got as far as "5," and in 20 seconds or so more it may be allowed to point to "6," "7," or even "8." Generally speaking, it is not advisable, in dental administration, to give more oxygen than this. In general surgical cases, a progressive increase in oxygen is usually advisable—that is to say, the longer the patient has been inhaling the mixture, the greater should be the proportion of oxygen. Surgical procedures may usually be commenced in two and a half to three minutes after the face-piece has been applied; and at this moment it is important that the patient's symptoms should indicate that a diminution rather than an excess of oxygen is present in the blood. In regulating the increase or decrease of oxygen we must reckon what the *future* effects of any procedure will be. For example, if some phonation occur we should give somewhat less oxygen for a short period, but not necessarily till the phonation has ceased. We may usually turn back to the previous proportion of oxygen *before the symptoms of excitement have actually subsided*, knowing that they will subside in obedience to the lessened proportion of oxygen admitted several seconds previously. We have to pilot our patient along a narrow channel. On the one side we wish to avoid the clonic respiratory movements, etc., which prevent a free and lengthy intake of the anæsthetic; and on the other any inconvenient signs of incomplete anæsthesia. We must be sparing in our addition of oxygen in the case of those patients whose appearance suggests that they will be

likely to require what we may call, for want of a better term, a strong dose of the anæsthetic. Patients who are easily affected by anæsthetics—such, for example, as children and debilitated persons of both sexes—may invariably be anæsthetised by nitrous oxide with considerable percentages of oxygen. I find, for example, in anæsthetising such patients, that after 5 or 10 minutes' inhalation I can usually keep open about 20 of the minute oxygen orifices in the apparatus. A similar tolerance of large proportions of oxygen will be met with in asthmatics and other patients who may be suffering from any respiratory difficulties. In protracted administrations it may be advisable to admit an occasional breath of fresh air. Should inconvenient stertor arise, oxygen must be more freely admitted, and the jaw pressed forwards (p. 444) as in administering other anæsthetics. In general surgical practice it is a good plan to place a small mouth-prop between the teeth throughout the inhalation. The longest administration I have conducted without allowing even one breath of air was one which lasted 35 minutes.

C. EFFECTS PRODUCED

First Degree or Stage.—This is very similar to that already described as occurring under nitrous oxide. There is, however, one noteworthy difference, viz. that the presence of even a small percentage of oxygen more or less completely removes the *besoin de respirer* so common with pure nitrous oxide.

Second Degree or Stage.—Consciousness is lost a trifle later than with pure nitrous oxide; and the period that elapses between loss of consciousness and the establishment of anæsthesia is longer. Neurotic and alcoholic subjects, as well as those whose nervous systems have become undermined by excessive work, worry, etc., may move their arms or legs, laugh, or gesticulate during this stage. Excitement occurring during the administration may usually be at once stopped by diminishing the percentage of oxygen. In order to secure a tranquil anæsthesia the patient should invariably be kept as quiet as possible. During the first minute

· so of the inhalation slight stimuli may evoke rhythmical
ovements of the legs or arms, shouting, etc.—symptoms
hich would have been avoided had the patient not been
sturbed. The chance of excitement arising is greatly
ssened when, following the instructions of the adminis-
ator, the patient breathes the mixed gases freely and
eeply; for by so doing he not only more rapidly passes over
iat stage in which excitement is prone to manifest itself, but
l unpleasant sensations incidental to holding the breath—
ensations which may readily initiate distressing dreams—will
e prevented. The respiration during this stage not unfre-
uently becomes very deep and rapid, and then abruptly calm
r even imperceptible. There is no cause for anxiety in this
ipid respiration; it always coexists with a good regular
ulse and florid colour, and gradually gives place to tranquil,
nembarrassed, and distantly-snoring breathing, as deep anæs-
iesia approaches.

Third Degree or Stage.—When the typical anæsthesia of
itrous oxide and oxygen has become established, the patient's
ondition will be suggestive of natural sleep.

The **respiration** is usually remarkably calm and perfectly
egular during this stage. A barely audible inspiratory rough-
ess or snoring is not uncommon. The loud "stertor" of an
rdinary nitrous oxide administration is never met with, unless
he percentage of oxygen should be so small as to be useless
or oxygenating purposes. Respiration is rhythmically per-
ormed throughout; and the tumultuous thoracic and abdominal
iovements, sometimes witnessed when nitrous oxide is ad-
iinistered free from all oxygen, are strikingly absent. Owing
o there being less venous engorgement, and hence less swelling
f all parts within the upper air-tract, than when nitrous oxide
s given in the ordinary manner, patients with enlarged tonsils
iay be anæsthetised with comparatively little tendency to
bstructed breathing.

The **colour of the face and lips** varies. In some cases the
atient becomes a trifle paler than usual; whilst in others, and
specially in those previously pale from apprehension, the
olour becomes more florid. The duskiness and lividity so
ommon under pure nitrous oxide are, generally speaking,

entirely absent. As will subsequently be pointed out, it is sometimes necessary during the administration of the mixture either to bring down the proportion of oxygen below 10 per cent or to give pure nitrous oxide for a short period; and under such circumstances a variable degree of duskiness would of course ensue.

The **circulation** is well maintained during deep anæsthesia. The pulse is invariably accelerated; but it is neither as quick nor as small as the pulse under pure nitrous oxide.[1] I have administered nitrous oxide with oxygen to patients whose circulatory functions were at the time of inhalation seriously disorganised, and can testify to the very satisfactory manner in which the mixed gases have been taken. I have given the mixture to a patient in a half-fainting condition, sitting vertically in a chair, and have found an almost imperceptible pulse to become perceptible and of fair volume during the inhalation. Dr. Leonard Hill, working with his "sphygmometer," finds that the arterial pressure either rises slightly or remains constant.

Clonic **muscular movements** are usually conspicuous by their absence; and the so-called "jactitation" of nitrous oxide is, with the rarest exception, never witnessed. A minor degree of tonic spasm in the muscles of the neck, back, and extremities is often manifested, more especially as the immediate reflex result of the operation. Opisthotonos very rarely occurs.

The condition of the **eyelids, globes, and pupils** deserves special notice. The eyes usually remain closed throughout the administration. During the first 45 or 60 seconds any attempt to raise the upper lid will cause a reflex tightening of the orbicularis. This spasm, however, gradually passes away as the inhalation proceeds, and at the end of about 75 or 90 seconds the upper lid may usually be raised without resistance. The eyeballs will now be found to be fixed, and in many cases turned to the right or left. In some instances there may be observed slight oscillatory movements of the globes; not as rapid as those of ordinary nystagmus, but not so slow as those which

[1] Dr. Walter Broadbent (*Brit. Med. Journ.*, 8th July 1899) publishes an interesting pulse tracing under nitrous oxide and oxygen, showing some lowering of tension, which he believes is due to peripheral dilatation.

would indicate conscious observation on the part of the patient. The pupils are variable. As a general rule they are of moderate size. Wide dilatation, such as that usually met with under nitrous oxide free from oxygen, is distinctly rare. I have on many occasions witnessed contraction and dilatation of the pupil in almost immediate response to a greater or less percentage of oxygen. The pupils may of course reflexly dilate during the extraction of a tooth, even though the patient be absolutely unconscious and free from all pain. The conjunctival reflex is, in the vast majority of cases, quite absent, though the cornea is generally sensitive to touch. After a protracted administration, however, the cornea loses its sensibility.

Reflex **phonation**, as for example during tooth extraction, is, as with nitrous oxide itself, sometimes met with; but, as the anæsthesia when oxygen is used is deeper than when nitrous oxide alone is employed, such phonation is much less likely to arise. Of 153 dental cases I noted it, more or less, in 29.

Anæsthesia is known to be present by one or all of the following signs:—

1. The conjunctival reflex is lost.
2. The breathing is regular and tranquil, or is softly snoring in character (like the breathing of good chloroform anæsthesia).
3. The arms are flaccid.
4. The eyeballs are fixed or present slight oscillatory movements.

Sometimes the conjunctival reflex persists, in which case the breathing or muscular flaccidity must be relied upon. Should it be found advisable, as often happens, to give a smaller percentage of oxygen than usual, or should the patient be extremely susceptible to the anæsthetic gas, *slight* irregular muscular twitchings (mild "jactitation") may arise. In some cases the muscular system, instead of being relaxed, is rigid at the acme of anæsthesia, but such cases are exceptional. Alcoholic patients appear to be particularly liable to this rigidity.

D. NITROUS OXIDE AND OXYGEN IN DENTAL SURGERY

The anæsthesia produced by this system of anæsthetisation is particularly suited to dental operations; in fact, so far as

my experience goes, there is no other form of anæsthesia which can be compared to it.

The **period of inhalation** requisite to secure deep anæsthesia varies considerably in different cases; some patients being, for reasons already given, far more quickly and deeply affected by nitrous oxide than others. Of sixty-seven carefully (métronome) timed dental administrations with the apparatus above described I found the average period of inhalation to be **110·5 seconds**, a figure which represents the average period of inhalation found necessary to provide the operator with a subsequent anæsthesia of sufficient duration for the performance of an average dental operation.

In sixty-nine carefully (métronome) timed dental administrations the average **available period of anæsthesia** was **44 seconds**. It is right, however, to point out that great variation occurs in the duration of this period. The longest anæsthesia was 90 seconds, the shortest 21 seconds. Within certain limits, the longer the administration the longer will be the subsequent anæsthesia. The following figures are of interest in this connection:—

Anæsthetic employed.	Average Period of Inhalation for Dental Operations.	Average Period of Resulting Anæsthesia.
Nitrous oxide *per se* . .	about 56 secs.	about 30 secs.
Nitrous oxide mixed with a percentage of oxygen sufficient to prevent all asphyxial phenomena	about 110 secs.	about 44 secs.

For further remarks on dental operations see p. 161 *et seq.*

E. NITROUS OXIDE AND OXYGEN IN GENERAL SURGERY

So far as the simple maintenance of unconsciousness is concerned, this system may be regarded as applicable in general surgery; but as the surgeon of the present day very properly requires that his patient shall not only be unconscious but tranquil and immobile, it can hardly be contended that the anæsthesia from nitrous oxide and oxygen meets his requirements. As already pointed out, the anæsthesia is comparatively

light; and inconvenient reflex movements are prone to arise. It is true that the tendency to these reflex phenomena gradually lessens as the administration proceeds; but this is of little moment. Skin incisions, particularly about the lower extremities, and procedures within and about the rectum or vagina, are especially liable to lead to inconvenient movements. Alcoholic subjects, those who smoke to excess, highly neurotic persons, and vigorous young men and women are especially likely to evince these reflex phenomena. Moreover, repeated administrations of nitrous oxide and oxygen have a tendency to induce a comparative insusceptibility on the part of the patient, so that it becomes increasingly difficult to secure the desired degree of relaxation and freedom from movement. In addition to these objections to the system, it must be remembered that the administration of the two gases for a lengthy operation is by no means an easy matter; for not only is it difficult to be certain of having a sufficient supply of the two agents, but it is somewhat irksome to carry out the numerous manipulations for a protracted period. It was at one time thought that this system of anæsthetisation would prove to be invariably free from after-effects, but such is unfortunately not the case. Other things being equal, there is certainly less risk of nausea and vomiting than after ether or chloroform; but I have notes of several cases in which these after-effects assumed distressing proportions. In one case in which I administered the gases for the removal of the breast, the vascularity of the parts was as great as it usually is under ether; and the patient, who was particularly anxious to avoid this latter anæsthetic, because of previous experiences, was sick for many hours after the administration. It is true that such cases are very exceptional, but they must not be ignored.

I have administered nitrous oxide and oxygen for Syme's amputation, lithotrity, removal of the breast, excision of varicose veins, varicocele, removal of ossicles of internal ear, resection of the patella, removal of necrosed bone from a tubercular hip, several intra-uterine operations, the removal of epitheliomatous glands from the groin, and for a large number of minor surgical operations; and I think that *in carefully selected cases* this plan of anæsthetisation has much to recommend it. As already

indicated, good and tranquil anæsthesia can only be secured *in certain types of subjects;* and even when dealing with such types there are only certain operations that should be undertaken. For example, to attempt to anæsthetise by this system a vigorous, thick-set, alcoholic man for a rectal operation would be but to court failure. On the other hand, to employ this form of anæsthesia for some comparatively trifling operation upon a middle-aged and non-excitable lady who had on a previous occasion been greatly distressed by the after-effects of ether or chloroform would be the best line of practice.

In order to obtain the best results the patient should be as carefully prepared as for any other general anæsthetic, and special attention should be paid to the posture in which the administration is conducted (p. 138). When cases are thus carefully

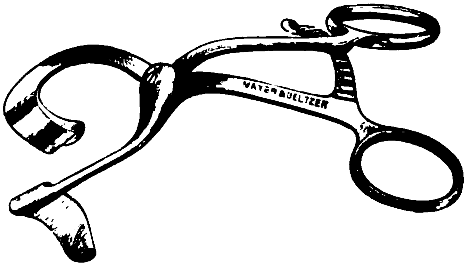


FIG. 25.—Doyen's Gag.

selected, and when attention is paid to the points to which I have referred, the very best results may, as a rule, be expected. and an almost ideal form of anæsthesia induced and maintained with little or no after-effects. I find this kind of anæsthesia invaluable in many short operations in addition to those of dental surgery. Thus, when the surgeon wishes to remove tonsils or adenoid growths in a child, and requires but a short anæsthesia, the mouth may be propped open by means of a dental mouth-prop (Fig. 13, p. 201) or a Doyen's gag (shown in the accompanying figure); and after a three minutes' administration an excellent anæsthesia will result of sufficient duration for such operations. Again, when a short unconsciousness is required during painful dressings, or manipulations are needed after grave operations, nothing answers better than nitrous oxide and oxygen.

F. DANGERS CONNECTED WITH THE ADMINISTRATION

There is no form of anæsthesia at present known which is o devoid of danger as that which results from nitrous oxide when administered with a sufficient percentage of oxygen to prevent all asphyxial complications. I have employed this system up to the present time (January 1901) in about 14,000 cases, as near as I am able to estimate, and with the exception of two or three cases, in which, owing to the percentage of oxygen having been insufficient, transient respiratory embarrassment arose, I have had no cause for anxiety. Owing to the fact that little or no strain is thrown upon the circulation, persons with feeble and dilated hearts are anæsthetised by nitrous oxide and oxygen without that slight risk which obtains when the former gas is administered alone. Moreover, those patients who, by reason of senile or other changes in the thoracic parietes, pleuræ, or lungs, might evince symptoms of embarrassed breathing at the acme of ordinary nitrous oxide anæsthesia, are certainly less likely to do so in the presence of oxygen. So far as I am aware, no fatality has yet been recorded under nitrous oxide and oxygen.

G. RECOVERY : AFTER-EFFECTS

The recovery from the effects of this mixture is usually very satisfactory, though not quite so speedy as from nitrous oxide alone. We can hardly expect this, indeed, to be so, seeing that the inhalation is invariably longer when nitrous oxide is given with oxygen. There is an absence of that abrupt return to consciousness which is met with in the case of unmixed nitrous oxide. In dental practice patients will be found to be a little more dazed than after nitrous oxide alone. The difference, however, is slight; and when the inhalation has been short there is practically none to be detected. It is only when an inhalation of two to three minutes, or longer, has been conducted that the more tardy recovery manifests itself. The longer the inhalation, the greater will be the tendency to after-effects. **Nausea** or actual **vomiting**, although rare, is more

common than after nitrous oxide alone—a fact which must not be lost sight of (see p. 263).

In a few instances I have met with **pallor, feebleness of pulse, and faintness** after an administration; but I have never seen such symptoms assume grave proportions.

I have notes of three cases of **transient maniacal excitement** immediately after the administration. In all three cases the patients were men of powerful build.

H. ILLUSTRATIVE CASES

In the following table are given four illustrative dental cases. The times were taken by a métronome, and an assistant recorded the symptoms of the patients. The table shows the effect of more and less oxygen, the intervals at which this gas was admitted, and many other points.

Illust. Case, No 1.

A typical case.

Sex and Age.—M. 18.

Description.—Fairly nourished; good colour. A postman.

A.—Period of Inhalation.

s.	Oxygen Indicator at	*Symptoms.*
0	2	
8	3	Six breaths taken.
3	4	
9	4	Deep respiration.
1	5	
2	5	Quieter breathing.
8	6	
0	6	No conjunctival reflex.
9	6	Pupils 3½ mm. in diameter.
8	6	Inhalation stopped.

B.—Available Anæsthesia after Removal of Face-piece.

cs.	*Symptoms.*
3	Good colour.
9	No movement or phonation.
21	Opposite side of mouth being operated upon.
30	Operation over.
12	Anæsthesia at an end.

Teeth or stumps extracted.—4.
General result.—Typical.
Remarks.—No pain. No phonation or movement; no stertor or muscular twitching; good recovery; dreamt he was at his work.

Illust. Case, No 2.

A typical case except for slight duskiness. See remarks.

Sex and Age.—F. 33.

Description.—Spare; sallow.

A.—Period of Inhalation.

Secs.	Oxygen Indicator at	*Symptoms.*
0	2	
12	3	
24	4	
39	5	
51	6	
57	6	Twitching of eyelids.
66	6	Conjunctival reflex not abolished.
72	7	
78	7	Restless movement in chair.
81	5	
84	3	
87	2	
93	3	Movement ceased.
96	5	
108	5	Slight conjunctival reflex.
120	5	No conjunctival reflex.
123	5	Breathing quicker and more audible.
126	5	Inhalation stopped.

B.—Available Anæsthesia after Removal of Face-piece.

Secs.	*Symptoms.*
3	Distinctly dusky.
9	Very slight phonation.
12	Normal colour returned.
24	Some movement of legs.
30	Anæsthesia at an end.

Teeth or stumps extracted.—4.
General result.—Good but not typical.
Remarks.—Restless movements probably due to too much oxygen at 72 secs. Movements quite controlled by less oxygen (more N_2O); but some duskiness at end due to this diminished quantity. Otherwise typical. No "stertor" or "jactitation."

Illust. Case, No. 3.

Long inhalation and long anæsthesia after.

Sex and Age.—F. 33.

Description.—Fairly well-nourished; fair complexion.

A.—*Period of Inhalation.*

Secs.	Oxygen Indicator at	*Symptoms.*
0	2	
18	3	
30	4	
36	5	Quicker breathing.
54	6	
60	6	Quieter breathing.
72	6	Soft snoring.
81	6	Ditto.
96	7	Distinct conjunctival reflex.
108	7	Snoring passing off. Slight rigidity of neck.
132	7	Tendency to turn head to left. Conjunctival reflex still present.
150	8	Very slight snoring.
171	8	Conjunctival reflex slight.
177	8	Some phonation.
180	8	Breathing quicker and more audible.
186	8	Inhalation stopped.

B.—*Available Anæsthesia after Removal of Face-piece.*

Secs.	*Symptoms.*
9	Some phonation.
18	Phonation ceased, operation proceeding.
27	Slight rigidity, good colour.
48	Movement of hand towards head.
66	Extraction finished.

Teeth or stumps extracted.—4.

General result.—Very good, barely typical.

Remarks.—She slightly felt the last stump. Probably deduct 6 secs. from 66 above mentioned. Instance of long administration and long anæsthesia. A good deal of oxygen given.

Illust. Case, No. 4.

Too much oxygen given intentionally for purposes of demonstration. Excitement thus produced easily controlled.

Sex and Age.—F. 37.

Description.—Healthy appearance. (Pulse 120 before prop inserted.)

A.—*Period of Inhalation.*

Secs.	Oxygen Indicator at	*Symptoms.*
0	3	
6	3	Pulse 132.
18	4	
21	4	Pulse 144.
33	4	Average breathing.
36	4	Tranquil breathing.
42	5	
51	5	Very calm breathing.
54	6	
66	5	Slight evidences of approaching excitement.
69	4	
72	4	Some phonation.
78	3	Restless movement in chair with tendency to slip forward.
81	3	Pulse 120.
84	4	
93	5	Quite quiet.
102	5	Inhalation stopped.

B.—*Available Anæsthesia after Removal of Face-piece.*

Secs.	*Symptoms.*
3	Colour a trifle dusky.
15	No phonation.
21	Conjunctiva insensitive.
36	Anæsthesia at an end.

Teeth or stumps extracted.—1.

General result.—Very good, barely typical.

Remarks.—Started with oxygen indicator at "3" instead of "2," and turned it to "4" in 18 seconds.

CHAPTER X

ETHER

A. APPARATUS AND METHODS OF ADMINISTRATION

We have now to consider the chief methods for the administration of ether *per se, i.e.* independently of any other anæsthetic. As will subsequently be pointed out, ether may, with much advantage, be preceded by nitrous oxide (Chap. XIV. p. 402), or a small quantity of the A.C.E. mixture (Chap. XIV. p. 413). But if these agents be not at hand, or if simplicity in procedure be desired, ether must be given throughout.

Ether may be administered—

I. By the **open** system—a plentiful supply of atmospheric air gaining access to the lungs throughout the administration;

II. By the **semi-open** system—the inhaler employed limiting to some extent the access of atmospheric air without in any way retaining the expiratory products for re-breathing;

III. By the **close** system—the air supply being intentionally restricted, and the expiratory products retained for re-breathing;

IV. **In conjunction with oxygen** instead of atmospheric air; or

V. By the introduction of the vapour into the rectum **(rectal anæsthetisation)**.

I. *The Open System of Etherisation*

As a general rule it is impossible to produce deep anæsthesia by this system, although it may be used in infants, in extremely exhausted subjects, or in patients who have been

for some time deeply anæsthetised, and who, in consequence, require minimal doses of ether to maintain insensibility. Ether is added, in small quantities at a time, to a folded cloth or handkerchief, or a Skinner's mask.

II. *The Semi-open System of Etherisation*

When ether was first introduced it was administered by means of a towel folded and pinned into the shape of a cone, and at the apex of this cone a sponge was placed for the reception of the ether. The sponge was usually wrung out in warm water before use. The anæsthetic was poured upon the sponge in small quantities at a time, and the cone applied, more or less continuously, to the face of the patient. Cone-shaped inhalers of felt, with an outer covering of mackintosh to prevent undue evaporation, were then devised, and are still used by some. These cones are also furnished with sponges, and are slightly open at their apices, so that air may gain admission. They have been used for a great many years both in England and in America, and certainly have the merit of simplicity. One of the best of the open ether inhalers is shown in Fig. 26. It is known as Rendle's mask. The inhaler is made of leather, celluloid, or metal, and has numerous holes at its rounded end. A long large-mouthed bag of domett or flannel is used as a lining, its mouth being brought back over the mouth of the inhaler, so that when the latter is applied to the patient's face a soft surface of domett or flannel comes against the cheeks. A sponge is placed at the bottom of the inhaler, and ether is poured upon it. Inhalers of celluloid or metal are preferable to those of leather, as they are more readily cleansed. In America the apparatus shown in Fig. 27, and known as Allis's ether inhaler,[1] is largely used. It consists of a cylindrical metal frame (M) with long spaces punched out of its circumference, so that a bandage may be threaded backwards and forwards across the open cylinder, as shown in the figure. The metal frame is enclosed by a leather case (L) which is longer than the metal frame, so that the part of the leather case which is unoccupied by the frame may fit the face of the patient. Ether is

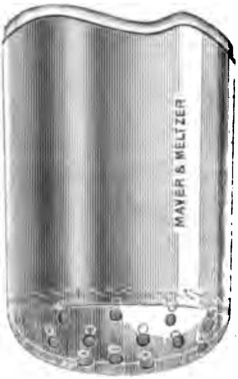


FIG. 26.—Rendle's Inhaler.

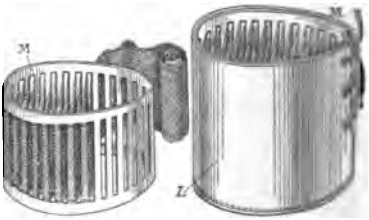


FIG. 27.—Allis's Ether Inhaler.

[1] *Philadelphia Medical Times*, No. 162. Fig. 27 is copied, by Dr. Turnbull's kind permission, from his work on Anæsthetics.

·opped or poured upon the bandage as required. By this arrangement e breath passes over a large surface of bandage moistened with ether. llis's inhaler has not been used, at all events to any great extent, in this untry. Numerous other semi-open ether inhalers have been devised, it space forbids me referring to them here.

The **administration of ether by means of a semi-open inhaler** such a simple procedure that details are hardly necessary. n adults a drachm or two should be first placed within ne inhaler, and the latter held that distance from the face hich is found to be necessary in order to avoid cough or olding the breath. Too strong a vapour will cause instant losure of the larynx and a sense of suffocation. Allis's nhaler certainly has the advantage of allowing of a more radual increase in the strength of ether than is possible n cone-inhalers, which have to be removed from time to time n order to be re-charged. The administrator must steer etween too sparing and too liberal a use of the anæsthetic. If very small quantities be given, the patient may never pass beyond the stage of ether intoxication. On the other hand, if too pungent a vapour be given, the patient will experience the most horrible sense of suffocation, the breath will be held for prolonged periods, and violent struggling will probably arise. It is therefore best to start with a vapour diluted with air, according to the indications present, and when the patient is getting dazed and losing consciousness to gradually but progressively increase the strength of vapour. The effect of the ether upon the larynx must be watched, and the quantity regulated accordingly. Respiratory rhythm is always interfered with, more or less, by swallowing movements, temporary closure of the larynx, etc. By degrees, however, the larynx grows accustomed to the vapour; it becomes less sensitive, and respiration more regular. When once unconsciousness has become established any tendency to excitement or struggling must be met by a more continuous application of the anæsthetic. There is not that danger in pushing ether at this stage that we know to exist with chloroform. Should the sponge of a semi-open inhaler become frozen by the evaporation of the ether, it must be removed and immersed in warm water before being again used, other-

wise it may be impossible to obtain a sufficient quantity of ether from the inhaler. When administering ether by the semi-open system large quantities of the anæsthetic may be needed to secure and maintain anæsthesia, especially in alcoholic and vigorous subjects. It would, for example, be necessary to have at hand at least two pints of ether in order to successfully anæsthetise an alcoholic and stalwart patient for an operation of considerable duration. A very large proportion of the anæsthetic is wasted; and the room may become almost unbearable from the presence of so much ether vapour. Excitement and struggling are far more common than when a close inhaler is employed. The risk of catarrhal bronchial and pulmonary affections is probably greater in administering ether by the semi-open than by the close system.

But although semi-open etherisation has many objections as a routine procedure, it has advantages in certain cases. There is nothing simpler than to pour ether from time to time into a cone; and when a totally inexperienced practitioner is called upon to anæsthetise a patient with ether, he will be less likely to do harm by administering ether as above described than if he employ a close inhaler. In very exhausted and cachectic patients, in those suffering from advanced morbus cordis and orthopnœa, and in many cases in which an operation for empyema is required, semi-open etherisation will be found to be of advantage. Moreover, when anæsthetising infants with ether this plan is very suitable.

III. *The Close System of Etherisation (by means of Bag-Inhalers)*

It is doubtful who first recognised the advantages of limiting the access of fresh air during the inhalation of ether vapour. The late Professor J. Morgan of Dublin appears to have been the first writer in Great Britain who drew attention to these advantages,[1] but he refers to Professor Porta of

[1] See an interesting article by Professor J. Morgan, entitled, "Ether *versus* Chloroform. On the uses of ether as an anæsthetic in surgical operations, as a safer and more efficient agent than chloroform in producing the avoidance of pain. With a description of an inhaler, and the mode of administration" (*Med. Press and Circular*, 31st July 1872).

Pavia[1] and to Dr. Smith of New York, both of whom had, prior to his (Dr. Morgan's) lectures, administered ether from a bladder

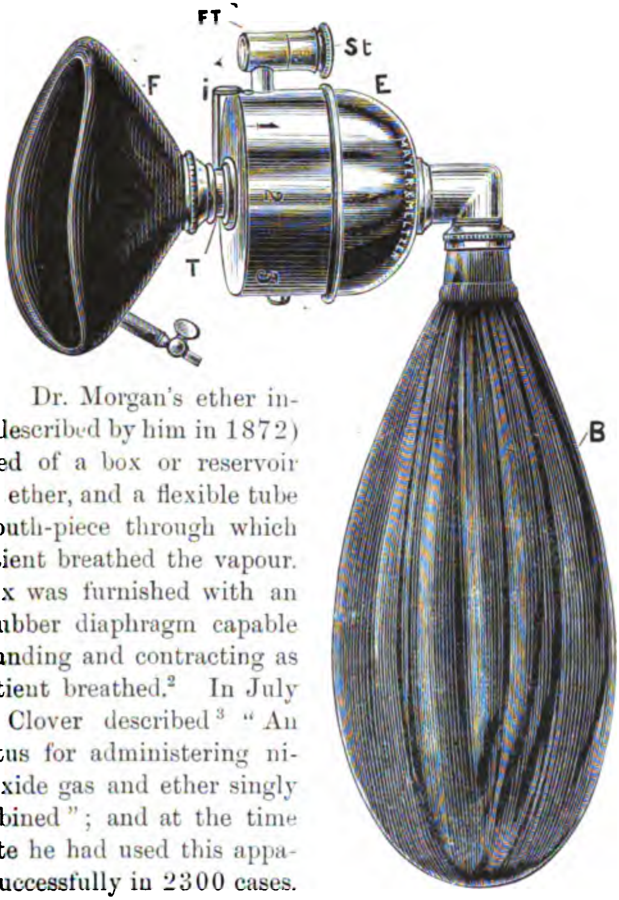


Fig. 28.—Clover's Portable Regulating Ether Inhaler (original pattern).

or bag. Dr. Morgan's ether inhaler (described by him in 1872) consisted of a box or reservoir for the ether, and a flexible tube and mouth-piece through which the patient breathed the vapour. The box was furnished with an india-rubber diaphragm capable of expanding and contracting as the patient breathed.[2] In July 1876, Clover described[3] "An apparatus for administering nitrous oxide gas and ether singly or combined"; and at the time he wrote he had used this apparatus successfully in 2300 cases. The ether vapour, supplied from a reservoir, was breathed backwards and forwards from a bag attached to the face-piece, fresh air being admitted from time to time. In January 1877, Clover

[1] Asshurst, *Principles and Practice of Surgery*, p. 77.
[2] *Med. Press and Circular*, 28th August 1872, p. 165.
[3] *Brit. Med. Journ.*, 15th July 1876, p. 74. This apparatus will be referred to when discussing the administration of nitrous oxide with ether in Chapter XIV. of this Part.

described[1] his "Portable Regulating Ether Inhaler" (Fig. 28, p. 273). In February of the same year Dr. Ormsby of Dublin introduced[2] his apparatus (Fig. 35, p. 281) to the notice of the profession. Whilst Clover's ether inhaler has certain advantages over Ormsby's, the latter apparatus very favourably compares with the former in many respects. I shall therefore fully describe these two inhalers, the method of using each, and the advantages of the one over the other.

Clover's Portable Regulating Ether Inhaler

This most ingenious and useful apparatus is represented in Figs. 28, 31, and 32. When ready for use it has the appearance represented. F is the face-piece; E is the ether reservoir through which the air-current passes; and B is an india-rubber bag. When the face-piece fits the face accurately the patient breathes backwards and forwards into the bag. Mr. Pridgin Teale has very properly drawn attention to the importance of the face-piece in ether administration; and in an excellent

FIG. 29.—Irwin's Stopper.

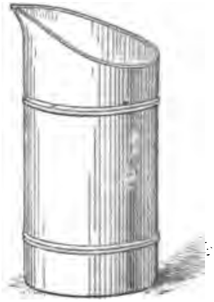


FIG. 30.—Measure for filling Clover's Ether Inhaler. (Half size.)

article[3] gives diagrams of good and bad face-pieces. Clover's apparatus possesses no valves, nor does it contain any contrivance for the admission of fresh air. The face-piece tightly plugs on to a tube T, which fits into one end of a shaft passing through the ether reservoir. The mount of the bag B fits into the other end of this shaft. By revolving the ether reservoir on the tube T the current is made to pass to any desired extent over ether. The apparatus is charged with ether at the funnel-shaped tube FT, the stopper of which is removed for the purpose. The best kind of ether bottle is one fitted with what is known as Irwin's stopper,[4] shown in Fig. 29. I have used this simple and excellent form of stopper for

[1] *Brit. Med. Journ.*, 20th January 1877, p. 69.
[2] *Lancet*, 10th February 1877, p. 218; also 9th June 1877, p. 86.
[3] *Encyclopædia Medica*, vol. i.
[4] *Lancet*, 24th Sept. 1898.

several years, and find it answers admirably. A little measure (Fig. 30), capable of holding about 1½ oz. of ether, is usually supplied with the inhaler, and is used for filling it with ether. The face-piece and bag hardly need further description; but the ether reservoir must be carefully considered, in order that the working of the inhaler may be understood.

In Figs. 31 and 32 the ether reservoir E and the tube T are shown in section. E consists essentially of a metal sphere tunnelled by the

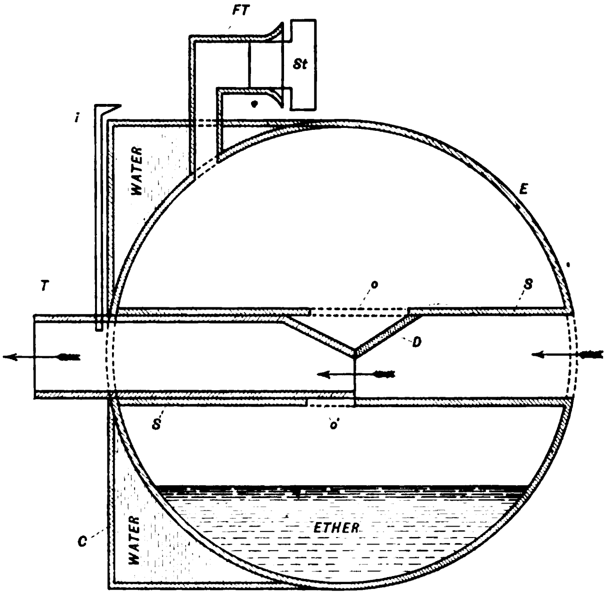


FIG. 31.—Section of Clover's Portable Regulating Ether Inhaler (original pattern). Indicator at "0." (Two-thirds actual size.)

shaft S, into which T fits. The sphere is the reservoir for the ether. The filling-tube (FT), closed with a stopper (St), is provided for charging the sphere with ether. Only one-half of the sphere is apparent in the finished apparatus, the other being covered in by a cylindrical cap or cover (C). The space which results is nearly filled with water by the makers of the instrument. This water-chamber prevents the apparatus from becoming too cold. When the temperature of the room is low, it is a good plan to immerse the inhaler in warm water for a few moments before use, by which plan the water in the water-chamber takes up and retains heat for a sufficient time to ensure a proper evaporation of ether in the adjacent sphere. About half-way along the shaft there are four large openings, two (O) on the upper wall of the shaft, and two (O′) on the lower. These allow of communication between the interior of the shaft on the one hand and the ether reservoir on the other. These openings are so large that the shaft S almost loses its continuity where

they occur. Projecting from the wall of the shaft there is a half diaphragm D, which closes up one-half of the calibre of the shaft, leaving the other half free. This half diaphragm is not fixed at right angles to the long axis of the shaft, but is sloped as shown. The tube T, upon which the face-piece plugs, passes into the shaft S. It has a whistle-shaped end which fits up against the half diaphragm D. It also carries a long rod or indicator (*i*), which points to figures on the circumference of the ether reservoir (Fig. 28). When the face-piece and tube T are fixed as in actual administration, the ether reservoir rotates easily upon T, and so the figures on the circumference travel one after the other past the

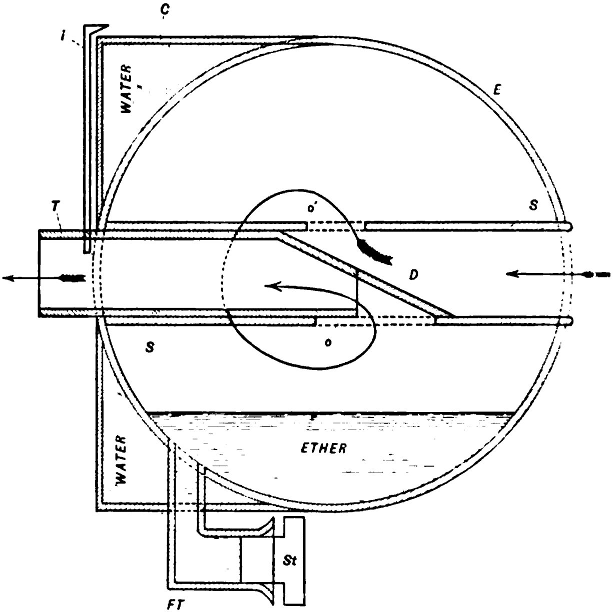


FIG. 32.—Section of Clover's Portable Regulating Ether Inhaler (original pattern). Indicator at "F." (Two-thirds actual size.)

indicator (*i*). If the indicator point to "0," and the face-piece and bag be attached to the ether reservoir, an inspiration will take the course shown in Fig. 31. It will pass straight through the shaft without entering the chamber containing the ether. The openings (O and O′) in the shaft are rendered unavailable, the upper ones (O) by reason of the half diaphragm D, and the lower ones (O′) by the whistle-shaped end of the tube T. When the ether reservoir is rotated, so that the filling-tube passes away from the indicator till the latter points to "F," the course of an inspiration will be very different. It will now enter the opening O′, and having passed over the ether (see long arrow), will escape at the opening O into the tube T, and so pass to the patient. The whole of the current will thus become deflected and pass over the ether. An expiration on

part of the patient would, of course, travel backwards to the bag by ctly the same route as that by which the inspiration came. The two :ional drawings show the course of an inspiration with the indicator ' O" and "F" respectively. The degree to which the current is made pass over the ether will depend upon the extent to which the ether ervoir is made to rotate upon the whistle-shaped tube, and this extent egistered by the indicator (i). With the indicator at "0" the current ı wholly direct one, passing backwards and forwards to the bag without ering the ether chamber (Fig. 33). With the indicator at "1," one arter is indirect, *i.e.* ses over the ether, and ee quarters are direct, pass to and from the g without being deflected. ith the indicator at "2," o quarters are indirect, d two quarters direct. ith the indicator at "3," ree quarters are indirect, d one quarter direct. ith the indicator at "F" "FULL," four quarters e. the whole of the rrent) are indirect, and ss over the ether in the amber.

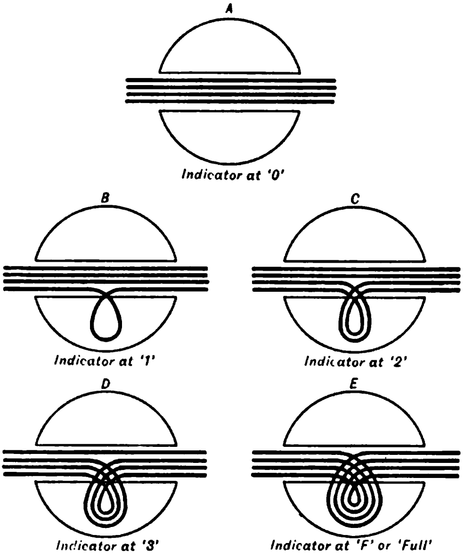


FIG. 33.—Diagram showing the extent to which the air-current passes over ether in Clover's Portable Inhaler when the indicator points to "0," "1," "2," "3," and "F." The whole current is diagrammatically represented by four lines.

The sectional drawings ' Figs. 31 and 32 apply the original pattern of lover's inhaler. Numerus modifications have been itroduced. Thus, Messrs. arth and Co. have devised n inhaler with a central ibe passing completely hrough it, and the mount f the bag fits into this tube instead of into the ether reservoir itself. By his plan the reservoir may be rotated without interfering with the posiion of the bag. The only objection to this otherwise excellent modificaion is that the air-way through the central parts of the inhaler is omewhat constricted at the point at which the current is made to pass ver the ether by the rotation of the reservoir.

Fig. 34 represents an inhaler which has recently been constructed for ne by Messrs. Barth and Co. It differs from Clover's original pattern in he following particulars: (1) Its internal calibre or air-way is very much larger; (2) instead of the ether reservoir rotating upon the central tube, the central tube rotates within the fixed reservoir; (3) the face-piece is screwed into the ether reservoir so that the latter cannot be unexpectedly

detached from the former ; (4) the ether reservoir can be adjusted, whatever the position of the patient may be, so that ether may be poured into it through its wide-mouthed filling-tube without removing the inhaler from the face. In order to secure these improvements, I found it necessary to materially modify the internal mechanism of Clover's original apparatus, and to have two separate inner tubes which are made to revolve as one tube by the indicating handle which fits into each. The large bag of the apparatus is distinctly of advantage not only in lessening the initial unpleasant sensations of re-breathing, but in reducing the asphyxial phenomena (stertor, cyanosis, and laboured breathing) of well-established ether anæsthesia. The apparatus is, moreover, specially useful, and indeed was more particularly designed, for administering nitrous oxide and ether in succession (p. 410). I am glad to take this opportunity of thanking Messrs. Barth and Co., the sole makers of this apparatus, for the patience and care with which they have made numerous experimental inhalers for me whilst engaged in perfecting this appliance.

FIG. 34.—The author's Modification of Clover's Portable Regulating Ether Inhaler.

Directions for using Clover's Portable Regulating Ether Inhaler (or any of the above modifications)

1. In cold weather, and particularly when about to anæsthetise powerfully-built or alcoholic subjects, partly immerse the ether reservoir in warm water for a few moments.

2. Fit on a face-piece of appropriate size; turn the indicator to "1" or "2"; pour in $1\frac{1}{2}$ oz. of ether; replace the plug; turn back the indicator to "0"; blow once through

e apparatus to free its air-way from any trace of ether ıpour; and attach the bag.

3. Request the patient to turn his head to one side; in-ruct him to commence breathing deeply through the *mouth*; ıd whilst he is doing so, gently apply the face-piece, press-g it rather more tightly during expiration than during .spiration, in order that the bag may become filled by cpired air.

4. Allow to-and-fro breathing for about half a minute ith the indicator at "0," and see that the bag expands and ›ntracts freely.

5. Gradually rotate the reservoir or move the indicator so ıat at the end of the first minute the indicator points to 1," at the end of the second minute to "2," and at the end f the third minute to "3." During the first minute or so he reservoir should be rotated or the indicator moved con-inuously yet almost imperceptibly. When consciousness has ›ecome lost, *i.e.* at the end of about 1½ minute, ether may be .dmitted rather more freely.

6. Any swallowing, "holding the breath," or coughing will indicate that the vapour is too strong, and the indicator must be moved back somewhat till respiration has again become unrestricted. Muscular excitement is very uncommon; should it occur, the administration must be pushed and it will soon subside.

7. When stertor commences, a single inspiration of fresh air should be admitted by raising the face-piece; and the administration may then be resumed. The admission of fresh air from this point onwards must be regulated by the suscepti-bility of the particular patient to this particular process of anæsthetising. Moreover, as the administration proceeds, more and more fresh air may be given without disturbing the anæsthesia. For example, whilst at the end of the first four or five minutes it is usually advisable to allow one inspiration of fresh air every ten or twelve breaths, at the end of half an hour one inspiration every three or four breaths may be per-mitted. Stertor, deep cyanosis, rapid and laboured respira-tion, and especially a strained form of expiration, are the indications for more air. In the case of patients with beards

more air gains admission between the face and the face-piece than in other subjects, so that the inhaler must be kept very tightly applied during the initial stages, and removed less frequently than usual during the later stages. The anoxæmic factor is as powerful as the ether factor in this system of anæsthetising. The less air given the less ether will be needed, and *vice versa.*

8. Some degree of cyanosis is to be expected, especially during the first two or three minutes. Later on in the administration it may be treated by removing the inhaler for fresh air from time to time.

9. Regular and snoring breathing, insensitive corneæ, and muscular flaccidity are the usual signs that deep ether anæsthesia has been induced.

10. The point at which the indicator should be kept after these signs have appeared must depend, as must the regulation of the air supply, upon the susceptibility of the patient. As a general rule " F " need only be reached when anæsthetising powerfully-built or alcoholic subjects. Less and less ether will be needed as the administration proceeds, so that at the end of fifteen minutes the indicator may usually be allowed to point to " 2 " or " $2\frac{1}{2}$," at the end of half an hour to " $1\frac{1}{2}$ " or " 2," and so on.

The above directions apply to the administration of ether to normal adult subjects, and it must be remembered that certain modifications will be needed when dealing with other cases. Strong, vascular, or alcoholic patients require large quantities of ether, and a free use of the anoxæmic factor, in order to obtain good results. On the other hand, children, feeble and cachectic subjects, and those whose vascular systems are affected by morbid or senile changes will demand careful treatment and the avoidance of any asphyxial strain.

Ormsby's Ether Inhaler

The Ormsby's inhaler usually supplied by the instrument-makers is constructed as represented in the accompanying diagram (Fig. 35). F is a metal (zinc) face-piece which can be bent to any desired shape. Its edge is guarded by an india-rubber pad (P), which can be inflated with air. To the other edge of the face-piece there is fixed a wire cage (C) contain-

ing a sponge (S). The bag (B) fits on to the face-piece, and its neck grasps the cage. The bag is covered with a loose netting by some makers of the apparatus. On the upper surface of the face-piece there is a circular opening (O) with a slot (Sl) cut in its circumference. Fixed into the mouth of this opening there is a funnel-shaped tube (Fu), which passes downwards and then divides, the two arms, which have perforated holes in them, coming into contact with the sponge. A cap (Ca) fits over O, and like O is furnished with a slot, which may be made to correspond to the slot (Sl) in O. When the slots correspond, air will gain admission to the apparatus; when they do not correspond, this communication with the air is cut off. When the cap is taken off, as in

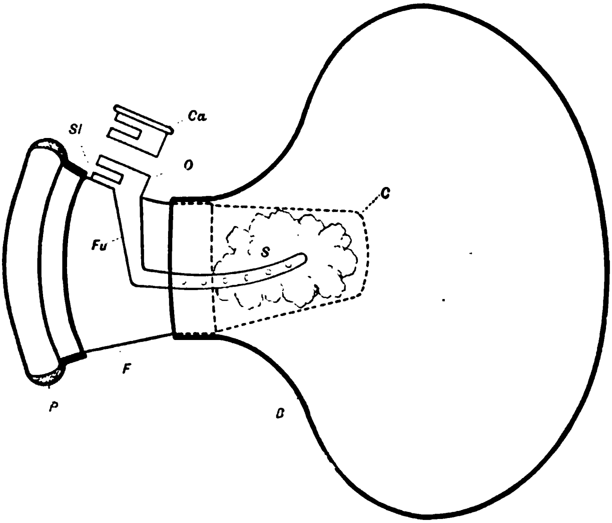


FIG. 35.—Diagram of Ormsby's Ether Inhaler. (Original pattern.)

the figure, the funnel-shaped tube (Fu) may be used for supplying ether to the sponge.

Experience with this useful inhaler has led to one or two slight modifications in its construction. In actual practice the funnel-shaped filling-tube is rarely used, for it is found to be more convenient to pour ether directly upon the sponge. Then, again, the bag usually supplied with the inhaler has proved to be far too small, especially for anæsthetising patients with full chest capacity. And lastly, any netting over the bag is unnecessary, as free respiration may thereby be restricted. Mr. Woodhouse Braine, who prefers Ormsby's apparatus to all others for ether-giving, has therefore used for many years an inhaler possessing no filling-tube and having a very capacious bag of red rubber without a network covering. The red india-rubber is little if at all affected by ether.

Fig. 36 represents a modification of Ormsby's inhaler which has the great advantage that it can be readily cleansed. The cage is made of fenestrated metal, not of wire, and the face-piece pad is detachable.[1]

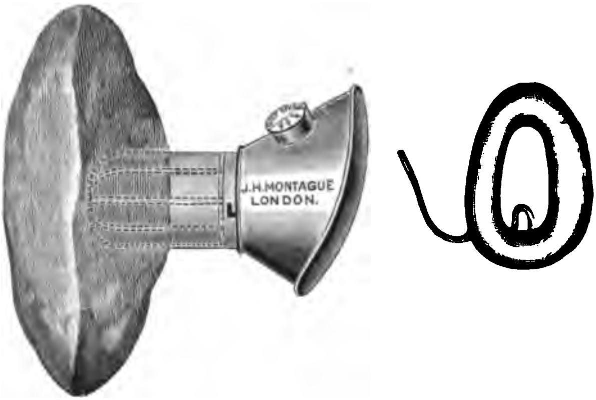


FIG. 36.—Carter Braine's Modification of Ormsby's Ether Inhaler.

Directions for using Ormsby's Inhaler

The method which is generally adopted is one of extreme simplicity.

1. The sponge of the inhaler is wrung out in warm water and inserted in the cage.
2. A small quantity of ether is poured upon the sponge.
3. The air-slot being open, the face-piece is very gradually applied to the face. At first it is held some little distance away, but it is then brought nearer and nearer, whilst the patient is encouraged to breathe as freely as possible.
4. Gradually close the air-slot.
5. Be prepared for the patient attempting to push away the inhaler, rising from the bed, etc. When once the administration has been fairly started, the inhaler should not be removed for air till signs of anæsthesia are approaching, or till more ether is required.
6. Should the sponge freeze, another one, wrung out as before, should be substituted, and fresh ether added.
7. When more ether is needed, about half an ounce at a time should be added to the sponge.

[1] See *Lancet*, 3rd December 1898.

8. From this point onwards the administration must be conducted upon the same principles as those above laid down for etherisation by means of Clover's inhaler.

The following alternative and ingenious method, introduced by Mr. Horace Pechell,[1] has the advantage of more gradually increasing the strength of vapour:—

1. A small quantity of ether is first poured into the bag of the inhaler.
2. A dry sponge is then introduced into the cage.
3. The face-piece is applied with the air-slot open.
4. The air-slot is gradually closed.
5. The ether is then made to moisten a large area of the bag in order to increase the strength of vapour breathed.
6. As the induction proceeds, the bag is gently tilted in order to allow the ether to reach the sponge.
7. Lastly, when once this stage of the administration has been reached, the quantity of ether which should be added to the sponge, and the frequency with which the face-piece should be removed, must be regulated by the principles already laid down.

Whilst Ormsby's inhaler is not so satisfactory as Clover's for *inducing* etherisation, owing to the fact that ether vapour cannot be so gradually admitted, it is certainly a very excellent apparatus for *maintaining* ether anæsthesia. It is hence a good plan, if Ormsby's inhaler is to be used for ether, to precede the administration of this anæsthetic by a small quantity of the A.C.E. mixture (p. 413). If, however, this method be impracticable, the anæsthetist must do his best to reduce, as far as possible, the initial discomforts which must always attend the earlier stages of etherisation. The differences in the type of the fully established ether anæsthesia resulting from Clover's inhaler on the one hand, and from Ormsby's apparatus on the other, have yet to be thoroughly explained. On many occasions, whilst administering ether, I have changed from a Clover's to an Ormsby's inhaler with marked improvement in the symptoms of the patient. For example, I have often known cyanosis to quickly vanish and the breathing to become less hampered by effecting this

[1] *Clin. Journ.*, 15th June 1898, p. 155.

change of inhalers during deep ether anæsthesia. It is probable that the narrow channels through which the patient has to breathe in Clover's apparatus may be responsible for differences of this kind. But there is another explanation, viz. that during the intervals in which the inhaler is removed from the face the narrower and more circuitous channels tend to retard diffusion between the bag and the outer air. In Ormsby's inhaler there is greater chance of diffusion, and expiratory products are hence not so likely to accumulate. The large-bore apparatus referred to above (p. 278) was designed with the object of combining, if possible, the advantages of both Clover's and Ormsby's inhalers, and it certainly throws less stress upon breathing and causes less cyanosis than the ordinary narrow-bore inhalers which have been so long in use. It appears, moreover, as far as my experience with it has gone, to produce less coughing and laryngeal irritation than Clover's original apparatus—an interesting fact considering that the bore is larger. Possibly the ether vapour is more evenly diffused through the inspired air than in the small-bore models. Whether it will be found to produce as good a type of deep ether anæsthesia as that obtainable by Ormsby's apparatus I am not as yet in a position to say.

IV. *The Administration of Oxygen with Ether Vapour*

There is little if any advantage to be gained by this system of anæsthetising except in certain special cases. In normal subjects we have seen that some degree of oxygen-limitation is actually advantageous in conducting etherisation. In patients who by reason of the presence of some respiratory affection or other condition do not display favourable symptoms under the "close" system of etherisation, rigorously applied, more air than usual may be allowed, or the semi-open system adopted. It is only in subjects whose respiratory functions are very seriously disordered (see p. 127) that oxygen may with advantage be administered with ether, and even in these cases, unless the patient be almost *in extremis*, and the heart seriously embarrassed or failing, it is questionable whether one cannot obtain an equally good result by the use of a mixture

of chloroform and ether. Provided the circulatory mechanism be in fair order there is every reason for administering a chloroform mixture in preference to ether. It is only when, as in bad cases of pleuro-pneumonia or empyema, the cardiac state is really to be feared, that chloroform or its mixtures should be avoided; and it is in such exceptional cases as these that the use of oxygen with ether is to be recommended. The best and simplest plan is to pass a small tube into a Rendle's inhaler and to keep up a constant stream of oxygen through this tube whilst administering ether from the sponge of the inhaler.

V. *Rectal Etherisation*

Rectal etherisation seems to have been first suggested by Roux in 1847 [1]; and Pirogoff practised it upon the human subject in the same year. The chief object in view was to facilitate the performance of operations within and about the mouth, nose, and pharynx. Liquid ether, sometimes mixed with water, was at first used; but it was soon found that more satisfactory results followed the employment of ether vapour. Within more recent times the practice has been revived by Axel Yversen and Mollière. The latter has given the method a fairly extensive trial,[2] and speaks well of it. He first tried Richardson's hand-bellows for introducing the ether vapour, but afterwards, in five cases, used an india-rubber tube which was connected with a bottle of ether immersed in water at 122° F. The ether vapour was allowed to gradually enter the rectum. As a rule, not more than 2 oz. of ether was used. After 5 to 10 minutes a taste of ether was experienced by the patient, and drowsiness was felt. The rectal administration was supplemented by inhalation if necessary. Excitement was rarely met with. In the same year Dr. Weir [3] published a case in which rectal etherisation proved fatal. The patient was a child of eight months; the operation was for hare-lip. Less than 2 oz. of ether was used. Depression, followed by melæna, supervened, and the

[1] *Journal de l'Académie des Sciences*, 1847, p. 146.
[2] *Lyon Médical*, 28th April 1884.
[3] *New York Med. Record*, 3rd May 1884.

child died next morning. Dr. W. T. Bull[1] also published seventeen cases. Melæna occurred in seven of these. Numerous other trials of the system have been recorded.[2] In some of these profound and prolonged stupor with cyanosis, contracted pupils, and asphyxial symptoms occurred. Quite recently Dr. Buxton has employed rectal etherisation for certain cases, and finds it "to answer admirably for operations about the mouth, nose, and post-buccal cavities, for intra- and extra-laryngeal operations, for staphylorrhaphy, and for operations for the relief of empyema."[3] He has also used the method for operations upon the tongue and jaws with success, and states that the plan gives greater facilities and freedom to the operator than any other with which he is acquainted. He employs an apparatus similar to that of Mollière, and finds that a temperature of 120° F. (for the water round the ether bottle) answers well. Further experience with the system is, however, necessary. If the risk of diarrhœa, melæna, and after-stupor could in any way be greatly reduced rectal etherisation would be strongly indicated in certain cases. But as matters stand, the process has too many objections attached to it to warrant us in employing it save in very exceptional cases.

B. THE EFFECTS PRODUCED BY THE ADMINISTRATION OF ETHER

With proper attention to a few cardinal points, and with a little practice, the administrator will find that he is not only able to materially lessen the disadvantages of ether as an anæsthetic, but that he can, without danger to his patient, or anxiety to himself, induce and maintain by its means a most satisfactory form of anæsthesia for surgical operations. Although there are often little difficulties to be overcome early in the administration; although the anæsthetic may cause a degree of respiratory activity which does not contrast very favourably with the more tranquil breathing of other anæsthetics; although the air-way is more liable to become temporarily occluded than

[1] *New York Med. Record*, 3rd May 1884.

[2] See *Med. Times and Gaz.*, 7th June 1884 (quoted in *Practitioner*, vol. xxxiii. p. 58); also *Brit. Med. Journ.*, 3rd October 1885, p. 659. [3] *Op. cit.* p. 86.

when employing chloroform, the anæsthesia from ether is as safe as one can reasonably expect profound surgical anæsthesia to be. Ether narcosis, moreover, strongly contrasts with that of chloroform in one important respect, viz. that when once it has become established, the warning given of approaching danger is, in practically every case, sufficient to enable the anæsthetist to rescue his patient. Under the influence of chloroform patients not unfrequently pass into a condition of danger with but little or no warning. The moderately healthy patient under ether may be raised into the sitting posture; he may be subjected to an operation before he is very deeply anæsthetised[1]; his air-supply may be so restricted that a considerable degree of cyanosis is occasioned; and yet his circulation will not show that liability to comparatively sudden fluctuations and depressions which, whatever may be their precise physiological explanation, most undoubtedly occur under chloroform. In addition to these important considerations, the respiration under ether is usually so obvious and audible that any alteration in the function of breathing may be at once detected: the sleep-like and inaudible respiration not unfrequently met with under chloroform is almost unknown under ether.

The phenomena of ether anæsthesia will necessarily depend upon the system and method of administration adopted. When the anæsthetic is given slowly and with a free supply of air, *i.e.* by the open system, there will be, as we have already seen, some difficulty in obtaining true anæsthesia, except in very young subjects. When the air-supply is slightly restricted, in other words, when the semi-open system is used, anæsthesia will more rapidly ensue, but excitement and intoxication phenomena will still be liable to manifest themselves. When, however, close methods are adopted patients may be anæsthetised with little or no movement or struggling, for the anoxæmia thus induced constitutes a powerful factor in the process. Owing to the rapidity and quietude with which patients may be anæsthetised by ether when the air-supply is properly regulated, we do not now, as formerly, have such a favourable

[1] Although the commencement or performance of an operation during imperfectly established ether anæsthesia is not attended by that risk which obtains under similar circumstances with chloroform, such a procedure should never be adopted save in exceptional cases.

opportunity of studying the so-called stages of the inhalation. For many reasons, however, and more especially for the correct understanding of exceptional cases, it is well that we should continue to speak of these degrees or stages.

First Degree or Stage.—In consequence of the pungent and rather disagreeable odour of ether, it is impossible to completely avoid all unpleasant sensations at the commencement of the inhalation. When well diluted with air, however, or cautiously administered during the re-breathing of a limited quantity of air as by Clover's inhaler, the irritant effects of the vapour will be greatly minimised. Should the vapour be too strong for the particular patient, the glottis will close, as in the early stage of swallowing, and a feeling of suffocation may be experienced. When the anæsthetic is so administered that closure of the glottis, repeated acts of swallowing, and cough are more or less completely prevented, respiration will rhythmically proceed, and will become deeper and quicker than normal. Disturbances of the special senses (p. 218) are common. The pulse is usually considerably accelerated. The pupils are large and very mobile.

Second Degree or Stage.—Loss of consciousness takes place abruptly. The patient passes into a condition in which, although memory, volition, and intelligence are abrogated, he will readily respond to stimuli. The response may have all the appearance of conscious response. Questions may be answered; but the answers will probably be nonsensical. Laughing, struggling, shouting, and singing may be met with at the commencement of this stage if the administration be slowly conducted. Such phenomena are more likely to occur in patients who require considerable quantities of the anæsthetic than in others. Struggling will often fail to appear if the slight restless movements of the arms and legs, which are common at this stage, be unrestrained. Holding the patient down, as well as other interferences, may readily evoke struggling. Hallucinations of sight and hearing often occur especially when ether is slowly given with plenty of air. The pupils are still mobile, and usually more or less dilated. The muscular system is for the most part thrown into a state of tonic contraction; but clonic movements may sometimes be witnessed towards the close of the stage. In exceptional cases

a fine tremor, known as "ether-tremor," may occur.[1] This phenomenon appears to belong more to the second than to the third stage of etherisation, seeing that it may usually be controlled by a deeper anæsthesia; so that it is referred to here. Mucus and saliva are freely secreted, especially in young and florid subjects. The features become flushed, the conjunctivæ injected, perspiration commences to break out over the face and other parts, and a harmless degree of duskiness, varying with the quantity of air admitted and with the patient's normal colour, will be observed. The pulse is quick and bounding. Any articulate language which may have been uttered becomes replaced by disjointed speech, which in its turn is followed by inarticulate muttering, and subsequently by mere syllables or expiratory noises. The breathing during this stage is inclined to be irregular and a trifle hampered, owing to the tendency to general muscular spasm. Temporarily suspended respiration may thus sometimes be met with, more especially in muscular subjects. The commonest cause for these slight irregularities in breathing at this stage is the employment of too strong a vapour. Clenching of the teeth from masseteric spasm, half-performed acts of swallowing necessarily interfering with respiration, and varying degrees of laryngeal spasm are one and all liable to arise from this cause. As the inhalation proceeds, however, the breathing grows more and more regular, and commencing stertor may be detected. Those muscles whose special office it is to carry on respiration now become incapable of being reflexly affected by the stimulus of ether, whilst others, whose spasmodic contraction would only indirectly affect the rhythm and amplitude of breathing (such as many of the muscles bounding and influencing the conformation of the upper air-passages), are now unable to interfere with free

[1] I have notes of several cases of "ether-tremor." In four of these it was considerable. The ages of three of the patients were 21, 24, and 30 respectively; no age is recorded in the other case. In one instance (the patient aged 30) the tremor came on before the operation commenced. In the patient aged 24, a healthy and well-developed man, undergoing an operation for varicose veins, the tremor was associated with a very large pupil and some lid-reflex. Julliard (*op. cit.*) states that he has never witnessed this phenomenon in women, and also that the patients in whom tremor occurs are invariably alcoholic or extremely nervous subjects. With the latter statement I cannot agree, as I have witnessed the symptom in question in young and non-alcoholic patients.

respiration, owing to their having become flaccid under the anæsthetic. In this manner the patient passes into the third stage of anæsthesia.

The reader must bear in mind that when the administration is properly conducted the duration of the second stage is far shorter than the above description might suggest. When a close inhaler is used, both the first and second stages may be passed over, and deep anæsthesia reached in from three to four minutes. But for purposes of analysis we have had to picture to ourselves a slow inhalation with more air than is usually advisable. Moreover, in the above description it has been taken for granted that no surgical or other procedure which would produce pain in a conscious patient has been in progress. The influences upon respiration and circulation which may result from commencing an operation before full surgical anæsthesia has become established are fully discussed elsewhere.

Third Degree or Stage.—When the respiration has become regular and stertorous, the cornea insensitive to touch and the extremities flaccid, the patient may be said to have passed into the third degree of anæsthesia, and to be ready for any surgical operation.

The **respiration** during deep etherisation is, with the rarest exceptions, always forcible and distinctly audible. Owing to the almost invariable presence of a small quantity of mucus in the fauces and larynx, breathing has a moist character in addition to its usual stertor. A little tendency to spasm of the masseters and adjacent muscles may remain for a while and necessitate the lower jaw being pushed forward from behind (see Fig. 55, p. 444). Such spasm, however, gradually subsides. The anæsthetist must bear in mind that unless he keep up a nearly continuous administration the patient will quickly pass back into the preceding stage, and irregularities in breathing will thus become developed. The rate of respiration is always markedly increased, varying considerably in different cases, and being dependent upon numerous circumstances, foremost amongst which must be mentioned the degree of air-limitation practised. Ether-stertor is most commonly due to the base of the tongue coming in contact with the pharynx, and as breathing usually takes place through the

nose the stertor usually has a nasal character. Pushing the lower jaw forwards from behind at once diminishes or stops the snoring. A tendency to laryngeal closure, either from too strong an ether vapour or from operative measures upon certain parts of the body (p. 449), is not uncommon, but rarely gives rise to difficulty. Sometimes the crowing breathing will persist throughout. When dependent upon the first-named cause the spasm will subside with less of the anæsthetic; when occurring during rectal or other operations upon sensitive parts more of the anæsthetic is usually indicated. It is hardly necessary to add that the amplitude, regularity, and even the rate of breathing will depend upon the conformation and size of the upper air-passages in addition to other factors.

The **circulation** of the etherised patient gives numerous clinical indications of its remarkable fulness and force. The heart's action is excited; the pulse full, bounding, and regular; the face is abnormally flushed; and incised parts, more especially in the neighbourhood of the neck, are very vascular. By means of Leonard Hill's "sphygmometer" it may be demonstrated that the arterial pressure remains constant at its normal level, or falls at most 5-10 mm. of mercury. The pulse, slower than during the second stage, but considerably quicker than normal, is usually from 80 to 110 per minute. It is not uncommon, however, especially in cases in which respiration is greatly accelerated from air-limitation or embarrassed from other causes, for the pulse-rate to be 160 or even more. In one (myxœdematous) patient I found it 190 per minute during deep anæsthesia, the only peculiarity of the case being that respiration was also very rapid. A roseolous rash sometimes makes its appearance upon the chest, neck, and other parts, when the vascular excitement is at its height.[1] Profuse perspiration is not uncommon.

The **pupils** of deep etherisation deserve special mention, as they differ from the chloroform pupils in some respects. They are usually of moderate size or slightly dilated, *i.e.* from $3\frac{1}{2}$ to $4\frac{1}{2}$ mm., and are active to light. The causes which

[1] Mr. Edgar Willett states (*St. Bartholomew's Hosp. Reports*, vol. xxxii.) that the eruption appears suddenly after three or four minutes' etherisation; that it gradually disappears after two more minutes; that it is most common in women; and that it usually affects the area supplied by the superficial cervical plexus.

may influence their size will be dealt with below when discussing the depth of anæsthesia necessary for surgical operations (p. 301). In certain cases in which a very deep anæsthesia is essential the anæsthetic may have to be administered till the pupil is considerably dilated, *i.e.* 5 to 5½ mm. Kappeler found from observations upon 150 cases that the pupil was contracted in 37 during deep etherisation.

The **position of the eyeballs** during deep anæsthesia is similar to that observed under chloroform (see p. 335).

The degree to which the **muscular system** is relaxed will depend not only upon the depth of etherisation, but upon the nature of the operation which is in progress. In some cases a minor degree of rigidity may persist for a considerable time. In several instances I have had occasion to believe that the muscular rigidity present in deep anæsthesia has depended upon the restriction of air, and have noticed that it has passed away with an increase in the quantity of air admitted.

It is hardly necessary to point out that the **colour of the face and lips** will, during this as during other stages, greatly depend upon the degree to which air is withheld.

C. DANGERS CONNECTED WITH THE ADMINISTRATION

General Consideration

In moderately healthy subjects the inhalation of ether is, like that of nitrous oxide, practically unattended by risk to life. The fatalities which have been reported have almost invariably taken place in exhausted or markedly diseased individuals.

On looking through the *Lancet* and *Brit. Med. Journ.* for ten years (1880 to 1889 inclusive) I find 27 fatalities from ether recorded as having occurred in Great Britain during that period. In 24 of these the patients were suffering from various diseases which had seriously impaired their general health. Of the three remaining fatalities, one is so imperfectly reported as to be useless for purposes of analysis; and one can hardly be ascribed to the anæsthetic, seeing that death was caused by vomited matter entering the trachea. The only casualty which occurred from the direct effects of ether took place in a patient whose general health was probably though not certainly good, and would most likely have been averted by tracheotomy. The following analysis of the 27 cases may be of interest:—

Table showing the Ether Fatalities reported in the *Lancet* and *British Medical Journal* as having occurred in Great Britain during ten years (1880-1889 inclusive).

Condition of Patient at Time of Administration.	Fatalities.
Group 1.—*Patients suffering from some pre-existing morbid state capable of impeding respiration during anæsthesia*	10
Empyema—2 cases (*B.M.J.*, 13th March 1886, p. 489; *B.M.J.*, 22nd April 1882, p. 589).	
Pleural effusion, ascites, dilated heart, and renal disease—1 case (*B.M.J.*, 20th Aug. 1881, p. 327).	
Bronchitis, emphysema, fatty heart, and adherent pericardium—1 case (*L.*, 24th Jan. 1885, p. 178. Also reported in *B.M.J.*, 13th March 1886, p. 489).	
Cancer of lung, liver, and upper jaw—1 case (*L.*, 27th Aug. 1881, p. 386, and *B.M.J.*, 25th Feb. 1882).	
Enlarged thyroid—2 cases (*L.*, 15th Nov. 1884, p. 895, and *B.M.J.*, 2nd May 1885, p. 887; *B.M.J.*, 15th March 1884, p. 508).	
Diphtheritic laryngitis—1 case (*L.*, 18th June 1881, p. 1014).	
"Cancerous growth in gums and throat"—1 case (*B.M.J.*, 23rd Feb. 1884, p. 378).	
Extensive pleural adhesion and œdema of lungs—1 case (*B.M.J.*, 18th Dec. 1880, p. 1000).	
Group 2.—*Patients suffering from cancerous or other affections producing extreme exhaustion*	10
Intestinal obstruction—3 cases (*L.*, 4th Sept. 1880, p. 376; *B.M.J.*, 15th Jan. 1881, p. 103).	
Uncomplicated asthenia—1 case (*B.M.J.*, 13th March 1886, p. 489).	
Feeble patients with abdominal tumours—3 cases (*B.M.J.*, 2nd May 1885, p. 887; *B.M.J.*, 15th July 1882, p. 103).	
Asthenia with morbus cordis—2 cases (*L.*, 27th May 1882, p. 892; *L.*, 3rd Dec. 1887, p. 1132).	
Large sarcoma of chest-wall, feeble patient—1 case (*B.M.J.*, 1st Jan. 1881, p. 14).	
Group 3.—*Patients suffering from renal disease and morbus cordis*	3
Vesico-vaginal fistula (a coloured woman)—1 case (*L.*, 20th April 1889, p. 800).	
Extreme obesity—1 case (*B.M.J.*, 22nd Nov. 1884, p. 1027).	
Diffuse cellulitis of palm and wrist—1 case (*B.M.J.*, 3rd Sept. 1881, p. 414).	
Group 4.—*Patients in moderately good health at the time of administration*	2
Sudden cessation of respiration before operation—? cause—1 case (*L.*, 3rd Sept. 1881, p. 430).*	
Vomited matters entered larynx and trachea—1 case (*B.M.J.*, 3rd Sept. 1881, p. 414).	
Group 5.—*Exhausted patient—ovarian tumour—death from pulmonary congestion seventeen hours after operation* (*B.M.J.*, 2nd May 1885, p. 887)	1
Group 6.—*Imperfectly reported* (*L.*, 6th Dec. 1884, p. 1027) .	1
	27

Special Considerations

1. **The Administration of an Overdose: Fourth Degree or Stage.**—Generally speaking, we may say that so long as the conjunctiva remains sensitive any symptoms of danger which the patient may exhibit will depend upon other causes than the administration of an overdose of the anæsthetic. The phenomena we are about to discuss, therefore, are phenomena occurring in association with an insensitive conjunctiva.

Should the administration of ether be carried too far, respiration will commence to show signs of failure. With this indication of danger the pupil will be more or less dilated; the colour dusky rather than pale; the eyelids slightly separated; and the pulse, although still remarkably good considering the respiratory depression, somewhat less forcible, and probably slower than it was previously.

The manner in which respiratory failure occurs will vary in different cases. In the majority of instances the breathing loses its stertor, becomes feebler and feebler, and then altogether ceases. In some instances, prolonged, difficult, and rather wheezy expiration, with shallow inspiration, may be observed, and may indicate a dangerous depth of narcosis. In others, again, the regular and deep stertor which has been present may be succeeded by jerky, intermittent, and gasping breathing, during which the respiratory movements may abruptly come to a standstill.

An occluded state of the upper air-passages, although possibly occurring in some cases as the result of too large a quantity of the anæsthetic, is probably more often associated with a light or moderately deep anæsthesia. It is quite conceivable that a falling together or spasm of the arytæno-epiglottidean folds, such as that which Lord Lister has described as arising under chloroform, may result from toxic doses of ether; but evidence on this matter is still needed.

Similarly, spasmodic fixity of the chest is probably more frequently associated with incomplete than with dangerously deep narcosis (see p. 296).

The all-important point concerning respiratory failure in moderately healthy patients under ether is this: *However such failure may arise, the circulation of the patient at the moment when breathing ceases is sufficiently satisfactory for remedial measures to be almost invariably successful.* The heart is not likely to fail unless restorative measures be too long delayed.

2. **Respiratory Failure occurring independently of an Overdose.**—The respiratory embarrassment which occasionally occurs in connection with the early stages of etherisation rarely gives cause for any anxiety. It usually passes away spontaneously as deep anæsthesia becomes established. As already mentioned (p. 289), masseteric spasm, swelling of the tongue and other structures within the mouth and nose, half-performed deglutition movements, and a varying degree of laryngeal spasm may one and all arise during the initial stages of ether administration, and may temporarily interfere with breathing. With ordinary care no trouble whatever will be experienced; for respiration will gradually become regular and unembarrassed. But should the administration be improperly and carelessly conducted, breathing may, in certain types of patients, cease for a considerable period, and remedial measures may be rendered necessary. Florid muscular subjects, with accurately-meeting teeth, are more liable than others to difficulties in breathing of this nature. The treatment which should be adopted for the prevention and relief of arrested breathing early in ether anæsthesia is discussed on p. 446.

Laryngeal spasm under ether rarely if ever culminates in actual arrest of breathing. Inspiration may become of higher and higher pitch; less and less air may enter the lungs; the colour may grow more and more dusky; but the respiration invariably becomes re-established within a short space of time. A similar condition of laryngeal spasm is met with under chloroform; but with that anæsthetic the tendency for breathing to become completely obstructed is decidedly greater (see p. 351). The deeper and stronger thoracic and diaphragmatic movements under ether are possibly better able to overcome the obstacle presented by the laryngeal spasm than the less

forcible movements under chloroform. For further remarks on this condition see p. 446.

In rare instances it has happened that breathing under ether has come to a complete standstill from spasm of the respiratory muscles—the chest being rigidly fixed. Some regard this state as resulting from a too free use of the anæsthetic; but there is good ground for the belief that, like laryngeal spasm, it most commonly arises quite independently of the administration of an overdose. Our knowledge upon the subject, however, is imperfect. Respiration may cease with alarming abruptness, and the administrator may find it impossible either to compress or expand the chest by the usual methods of artificial respiration. This fixity of the chest has been met with under chloroform as well as under ether (see p. 350). The only case in which I have seen the condition with ether was a very remarkable one. The patient was a man of sixty-nine years of age, whose usual pulse-rate was 30 per minute. He was only slightly emphysematous, and not bronchitic at the time. Under the influence of ether his expiration was rather strained. During properly established anæsthesia, breathing suddenly ceased; and though there was no occlusion of the air-way, it was absolutely impossible to move the chest-walls one way or the other by artificial means. The pupil at the time was moderately contracted. Fortunately, breathing spontaneously reappeared after about half or three-quarters of a minute.[1] The treatment of this condition is fully considered on pp. 448 and 463.

Just as there is a slight liability to temporarily-obstructed breathing immediately before deep anæsthesia is established, so there is a chance of its occurrence during recovery, *i.e.* at or about the time that the usual clenching of the teeth and swallowing which precede vomiting are prone to arise.

Respiratory embarrassment from these causes is always

[1] Mr. Holmes, Dr. Jacob, and others have recorded somewhat similar cases under ether. In two cases referred to in the *Brit. Med. Journ.*, 15th March 1884, p. 508, and 2nd May 1885, p. 887, respiratory failure occurred in patients suffering from goitre, and although tracheotomy was performed and a free passage to the lungs opened up, the chest-walls were so fixed that they could not be moved. In both cases a fatal termination ensued. It is highly probable that the use of forced artificial respiration (p. 463) offers the best chances in such cases as these.

unattended by symptoms of cardiac depression, unless, indeed, the embarrassment has existed for a considerable period.

3. **Circulatory Failure occurring independently of an Overdose.**—In moderately healthy subjects primary circulatory failure under ether may, for all practical purposes, be regarded as an impossible event. This remark does not, of course, apply to cases in which surgical shock takes place. The forms of early syncope which may be met with under chloroform, and to which attention will presently be directed (p. 338 *et seq.*), do not occur during the etherisation of healthy or moderately healthy subjects. This brings us, however, face to face with an exceedingly interesting and significant fact, viz. that in *bad* subjects, and especially in those with feeble, dilated, fatty, or otherwise diseased hearts, death may take place under ether with circulatory symptoms. It is true that in many of such cases some slight impairment of or embarrassment to respiration is present, but the patient dies from cardiac syncope during the slight asphyxial strain. It is in this way that neglected cases of strangulated hernia succumb during the process of etherisation, the "last straw" being the stage of struggling, the impaired breathing of impending vomiting, or the temporary presence within the fauces or larynx of vomited matters.

4. **The Passage of Foreign Bodies (Blood, Vomited Matters, etc.) into the Larynx and Trachea.**—For remarks on this subject the reader is referred to p. 452.

5. **Other Dangers.**—Cerebral hæmorrhage has been known to occur during etherisation,[1] but is of extreme rarity. Still, we must not lose sight of the fact that persons with very brittle arteries run a greater risk of this accident under ether than under less stimulating anæsthetics (see p. 310).

The pulmonary and renal complications which occasionally follow the use of ether will be considered below (E. After-effects).

[1] See a case reported in *Amer. Journ. Med. Sciences*, 1888, New Series, vol. xcv. p. 83. See also p. 310.

D. THE DEPTH OF ANÆSTHESIA NECESSARY FOR SURGICAL OPERATIONS

Having fully considered the various stages of etherisation and the dangers which may arise, we are now in a position to discuss the proper level of anæsthesia at which the patient should be kept during the performance of a surgical operation. As a general rule the administrator should endeavour to keep the etherised patient in the third stage of anæsthesia. A light narcosis, more especially in the earlier part of the administration, is liable to be attended not only by movement, but by inconvenient reflex phenomena such as spasm of the masseters, closure of the larynx, coughing, attempted vomiting, etc. There is in each case a particular and proper level of anæsthesia; and in order that this level may be satisfactorily maintained, the administrator must repeatedly consult certain guides or landmarks which will now be considered. Although this level may be readily found and demonstrated in any given patient undergoing an operation, it by no means follows that an anæsthesia attended by similar symptoms would be appropriate in an apparently similar case. Nor must the administrator take it for granted that, because he has discovered the proper degree of anæsthesia at which to keep his patient in the early part of the inhalation, such a degree should be maintained. The tendency to inconvenient reflex phenomena seems to lessen as the inhalation proceeds; and a depth of anæsthesia which would be out of the question at the beginning of an operation may usually be advantageously permitted later on. In deciding at what place or point we should keep our patient, we must be guided by a variety of considerations. We must bear in mind that, other things being equal, there are certain operations which demand a more profound anæsthesia than others. In the next place, there are some patients whose reflexes are so highly developed that very deep etherisation is necessary in order that good surgical anæsthesia may result. Then the point above mentioned must not be forgotten, viz. that after the operation has been in progress for some time, and more especially if much blood has been lost, and the patient is

owing even slight signs of exhaustion, we need not maintain at degree of narcosis which was proper at the commence-ent of the case. Clinical evidence goes to show that, although light ether anæsthesia is not to be recommended, there is ot that danger in it that exists in the case of chloroform; other words, reflex respiratory spasm more rapidly leads circulatory failure under the latter than under the former æsthetic. As regards reflex circulatory failure, the balance evidence is also in favour of ether. When the administrator as secured in his patient the signs of ether anæsthesia to hich reference has been made, he must narrowly observe hether the operation has any influence in modifying these gns. Given that no such influence has been detected, he ust keep his patient as lightly under ether as is compatible ith tranquillity and anæsthesia. He must find out his ındmarks in the particular case before him. By carefully bserving the effects produced by more and less ether pon—

(*a*) The respiration;
(*b*) The occurrence of swallowing-movements;
(*c*) The lid-reflex; and
(*d*) The pupils,

e will have but little difficulty in deciding upon the precise lace or level at which anæsthesia should be maintained. Having once established surgical anæsthesia, he will find that e is able to work in one case almost entirely by the respira-ion; in another by the occurrence of swallowing-movements; in another by the lid-reflex; in another by the pupil: and that a few exceptional cases will remain in which he will have to draw his inferences from all these or possibly from other signs.

(*a*) Of all the guides as to the depth of anæsthesia, **respiration** is by far the most trustworthy. When once surgical anæsthesia has become established, the continued administration of ether will increase the rate, depth, and stertor of respiration, whilst the temporary withdrawal of the anæsthetic will be found to have an exactly opposite effect. In this manner it is often possible to work entirely by the sound of the respiration, giving more ether when the breathing tends to

become less audible, and *vice versa*. A puffing of the lips with expiration is common in deep etherisation. In those cases in which it occurs it constitutes a good guide. In some patients there is an undoubted tendency towards slightly-obstructed breathing, more especially when the anæsthesia is not so deep as it should be. This tendency, which is thoroughly discussed on p. 289, must always be borne in mind. It is not a dangerous tendency, because by simply keeping the lower jaw pressed forwards from behind it disappears. It is most pronounced in muscular and vigorous subjects.

In many cases, and more especially in operations upon comparatively insensitive parts, and in protracted administrations, the respiration need not be kept as deep and stertorous as is generally desirable.

Sometimes an expiratory moaning sound is made, and may constitute, by its alternate absence and presence, in response to more or less ether, a valuable guide to the administrator.

A moist expiratory râle (? laryngeal or tracheal) indicates that less of the anæsthetic should be given; and the same may be said of "strained" or prolonged expiration.

(*b*) Given that the breathing has by a free use of ether been made deep, regular, and stertorous, a temporary withdrawal of the anæsthetic will not only be followed by more tranquil respiration, but very often a tendency to **swallowing**, or even coughing, will result, and so respiratory rhythm will become interfered with. The act of swallowing, easily recognised by placing the fingers over the larynx, is sometimes the first indication that the patient is emerging from deep anæsthesia, and when it occurs the administrator should at once give a little more ether if he wishes to avoid the coughing, straining, and vomiting which may follow.

(*c*) The **lid-reflex**, *i.e.* the closure of the eyelid when the conjunctiva or cornea is touched by the finger, although regarded by many as an untrustworthy guide, is in my own experience a most valuable indication of the depth of anæsthesia. In order that it may be properly made use of, the administrator must remember three facts. In the first place, it very commonly happens that, although no lid-reflex can be

ited by touching the margin of the lids or the conjunctiva
ering the sclerotic, a brisk closure will follow the applica-
ı of the finger to the *cornea*. In the next place, the
junctiva, by being repeatedly touched, loses its sensibility.
d lastly, there are degrees of this reflex, so that the patient
y require to be kept at a stage of anæsthesia bounded on
one side by considerable and on the other by very slight
-reflex. It is sometimes easier to feel than to see a minor
ree of lid-closure in response to touch. Moreover, when
m having frequently touched the conjunctiva of one eye its
ısibility has become diminished, the other eye may be tested.
is a good plan, indeed, to keep one conjunctiva, as it were,
reserve. Whether or no the administrator should allow the
-reflex to be present must depend upon the behaviour of
e patient when he is permitted to display a slight degree of
is reflex. Generally speaking, the lid-reflex should be kept
abeyance, especially during operations upon very sensitive
rts, and in patients whose reflexes are highly developed.
ı anæmic and weakly subjects, and in long operations, lid-
flex may usually be allowed, and will be found to be perfectly
mpatible with satisfactory anæsthesia.

(*d*) If carefully watched and studied the **pupils** will, in
ıost cases, afford valuable information. As the third stage
f anæsthesia becomes fully established they lose the mobility
hich they displayed in the first and second stages, and
radually settle down, so to speak, to a particular size for the
articular case. The anæsthetist should pay no attention what-
ver to the pupil till other signs have testified to the presence
f surgical anæsthesia. He should then notice whether any
eflex dilatation takes place when the operation is commenced.
Should the patient be very deeply under the anæsthetic no
uch dilatation, or very little, will as a rule result. Should
uch dilatation have taken place, it will usually gradually
ubside, but it may persist. The pupil will be of little service
as a guide until after about a quarter of an hour from the
beginning of the administration. The anæsthetist should now
watch its behaviour with more and less of the anæsthetic, and
he will usually have but little difficulty in deciding what size
of pupil indicates proper anæsthesia in the case before him.

We have already seen that the average pupil of deep etherisation is one of moderate size ($3\frac{1}{2}$ to $4\frac{1}{2}$ mm.); but in some patients a smaller, and in others a larger may be seen during satisfactory narcosis. The anæsthetist will usually observe that if he give less ether, the proper pupil of the particular case will get smaller; if he increase the depth of etherisation it will grow larger. He may see, for example, that if he allows a pupil of 4 mm. to come down to 2 or $2\frac{1}{2}$ mm., the patient will commence to swallow, strain, or show indications of cough. But the pupil does not always diminish in size in response to less ether, and increase in size in response to more. The matter is complicated by the frequent tendency of the pupil to grow large from reflex irritation caused by surgical or other procedures. This tendency is more marked when a light anæsthesia is maintained. Should this tendency to reflex dilatation be present, we can readily understand that it would be checked, in other words, the pupil would grow smaller by *more* of the anæsthetic. Neurotic and anæmic subjects, as well as children, not unfrequently exhibit a great susceptibility to reflex dilatation of the pupil throughout. In old people, on the contrary, and in those whose reflexes are not so highly developed, the pupil is less likely to fluctuate in size, and is usually smaller. Moreover, operations in the neighbourhood of sympathetic nerves are particularly prone to induce dilatation. This reflex enlargement of the pupil may be distinguished from what we may call the true toxic dilatation by observing the effects of more and less of the anæsthetic upon it. Suppose, for example, that the patient is undergoing an operation, and that his pupils are 5 mm. The question will arise, Are these pupils of reflex origin, or are they due to a deep anæsthesia? The problem may perhaps be solved by consulting the lid-reflex and other guides; but it may be more certainly settled by observing whether the pupil grows smaller or larger with less ether. If it become smaller with less ether the previous dilatation was probably due to a very profound anæsthesia: if it become larger with less ether the previous dilatation was probably of reflex origin. These considerations explain the apparent anomaly of an increased quantity of ether producing in one case a larger and in another a smaller pupil. Carrying

he matter one step further, the reader will see that, supposing he patient to possess a pupil of 5 mm., and the dilatation to e of reflex origin, more ether will first of all bring the pupil lown to, say, $3\frac{1}{2}$ mm., and then, should the administration be ontinued, will cause the pupil to again dilate to 5 mm., but his last dilatation will be the toxic dilatation. The progressive diminution in the size of the pupil, which may often e observed in a long operation, is probably due to the progressively lighter narcosis and the more liberal supply of air which are found to be permissible. Finally, we must bear in nind the fact, when considering the pupil under ether, that ny marked deprivation of oxygen will tend to effect an dditional increase in size.

E. AFTER-EFFECTS

Whilst ether is undoubtedly an exceedingly satisfactory anæsthetic so far as the general well-being and safety of the anæsthetised patient are concerned, it is unfortunately more liable than many other agents to lead to unpleasant or even fatal after-effects. This point has not perhaps received the attention to which it is entitled. The duties of an anæsthetist do not begin and end with the actual administration. Not only should the anæsthetic and method which are chosen produce satisfactory results at the time, but the administration should be so adjusted that the recovery of consciousness takes place speedily and satisfactorily. Now it is impossible to administer ether for a protracted operation without incurring certain risks which are absent in the case of chloroform or mixtures containing chloroform. The very important question hence arises: Do these risks counterbalance those of chloroform, which are, as we have seen, risks incurred *during* the administration? The reader is referred to other parts of the work for remarks on this point (pp. 110 and 111). All that we have to consider here is the state of the patient after etherisation.

Should the administrator have carefully observed the phenomena displayed by his patient during deep anæsthesia, and have noted the changes in the respiration, lid-reflex, pupils,

and other signs from time to time when less of the anæsthetic has been given, he will be in a position to foretell the order in which the symptoms of returning consciousness will manifest themselves. As a general rule, distinct signs of recovery should be evinced soon after the withdrawal of the anæsthetic. As pointed out (p. 494), recovery will take place more speedily and satisfactorily when the patient is turned over upon his side. Ether is often given in unnecessarily large quantities, the patient being saturated, as it were, with the drug. A prolonged stupor, unattended by cough, and characterised by slight duskiness and deterioration of pulse, may follow this injudicious and excessive use of ether. A minor degree of duskiness after this anæsthetic is not uncommon, and appears to be connected with the presence of mucus in the air-passages, and with the quieter breathing following the withdrawal of ether. Directly coughing or retching has occurred the patient's normal colour will become restored.

Ether generally leaves behind it a somewhat disagreeable taste, whilst its odour may be detected in the breath for a considerable period after the administration. The treatment of this and other after-effects will be fully discussed in the last chapter, to which the reader is referred. Provided the patient has been properly prepared (p. 186), that the administration has been skilfully conducted, that the purest ether has been used (p. 23), that the patient has been placed in a proper posture after the operation, and that the inhalation has not been very protracted, there will usually be but little trouble from **nausea, retching, or vomiting.** At the same time it cannot be denied that, *cæteris paribus*, such after-effects are more frequently met with in the case of ether than in that of chloroform. Protracted and dangerous vomiting, however, would appear to be rather less common with the former than with the latter anæsthetic. Transient retching, with the expulsion of a small quantity of colourless or yellowish fluid, is the rule rather than the exception. This so-called "vomiting" after ether is almost characteristic of the use of the drug. It comes on suddenly, is violent for the moment, and rapidly subsides, leaving the patient either dazed, half-conscious, and looking about him, or still unconscious and in a quiet sleep.

As a general rule, ether-vomiting takes place and is passed over whilst the patient is still unconscious, although repeated attacks are not uncommon, especially after lengthy administrations, and in certain types of subjects.[1]

On several occasions during the last fifteen years I have met with **hæmatemesis** after ether.

The patients have, as a rule, been in good condition, and partly by reason of their physique and partly from the nature of the operation it has been necessary to keep up a very deep anæsthesia. As a general rule, too, the patients in whom the hæmatemesis has arisen have not taken ether as smoothly as most cases, displaying jaw-spasm, cough, tendency to retch, etc., to such a degree that it has been thought advisable to substitute chloroform for ether. In one case—that of a florid boy of twelve—a persistent tendency to vomit occurred throughout the administration. Ether was first of all given, but after five minutes chloroform was substituted. The fluid which was then ejected contained no blood; but at the end of half an hour's deep chloroform anæsthesia hæmatemesis came on. I have also seen other cases in which this symptom has arisen after the ether-chloroform sequence; and one case in which it occurred after the A.C.E.-chloroform sequence.[2] In the majority of my cases the operation has been for the radical cure of hernia. The vomited material has either been porter-coloured or so similar to undigested beef-tea that its true nature has not been suspected. In one or two of the cases I have had the ejected fluid examined by competent authorities, who have confirmed my opinion as to its nature. The

---

1 Clover met with vomiting once in every 7 or 8 cases, but it is probable that minor cases of nausea are not included. Dr. Julliard (*op. cit.*) observed it in 314 out of 3654 ether administrations (=1 in 11 or 12). He does not state, however, whether he includes cases of transient ether nausea. Probably he does not. Dr. E. H. Jacob of Leeds (*Lancet*, 11th Oct. 1879, p. 539) recorded 1200 cases in which he used ether. He states that in no case was there severe vomiting. One patient in every five vomited before leaving the theatre, and a few others vomited afterwards. Mr. W. Rigden (*Lancet*, 31st Oct. 1874, p. 620) took notes of a considerable number of ether administrations, and met with vomiting in 50 per cent of the cases, but in 35 per cent it was very slight. It was noted as considerable in 15 per cent. He found that the vomiting after ether lasted a shorter time than that after chloroform. Mr. A. Fausset (*Lancet*, 18th June 1892, p. 1386) found that, putting aside abdominal sections, 47 out of 68 (=two-thirds) of the etherised patients at the Chelsea Hospital for Women vomited after the operation. In 21 cases (=one-third) no vomiting occurred. In 21 abdominal sections 18 vomited after ether. But it does not appear that *pure ethylic ether* was used for the administrations. Körte (*Deut. med. Zeit.*, 12th Feb. 1894) met with vomiting 60 times in 300 cases, or in one-fifth; but morphine was used in conjunction with the ether.

2 The patient was a bad subject of sixty-six, suffering from senile dementia, chronic bronchitis, and cardiac disease. Lithotrity was performed quite successfully. Hæmatemesis came on after the operation but gradually subsided.

hæmatemesis, which is probably capillary or congestive, gradually subsides and I have never known it give rise to any subsequent trouble or to recur to any serious extent.[1]

Hæmoptysis is rarely met with. Personally I have only seen one case during fifteen years' practice, and in this the hæmorrhage was slight and soon subsided.

Since the appearance of the first edition of this work I have had occasion to change my views concerning the frequency of **bronchial and pulmonary affections** after ether. By the introduction at the London Hospital of an improved system of note-taking, I have been able to obtain distinct evidence of the reality of ether-pneumonia. There have, in fact, been several well-marked cases within the past five years.

In one instance the patient, who had no previous chest affection, so far as could be ascertained, was seriously ill for several weeks, and eventually left the hospital with a crippled lung. In another the pneumonia proved fatal.

As mentioned in a footnote in my first edition, Dr. Jacob and Dr. Saundby drew attention, several years ago, to these bronchial and pulmonary sequelæ; and Dr. David Drummond[2] has lately done good service by publishing eight interesting cases of ether-pneumonia, in two of which the patients died. Up to the present time the pathology of these respiratory sequelæ has not been thoroughly worked out. Minor degrees of bronchial catarrh are not uncommon after ether, particularly after prolonged administrations and in predisposed subjects. It is held by some writers that undue exposure of cutaneous surfaces during an operation, or incautious ventilation afterwards, is generally accountable for bronchial or pulmonary attacks after ether; but the weak point of this argument is that such exposure and incautious ventilation do not give rise

[1] In one case at the London Hospital (which was under the care of Mr. Mansell Moullin) the patient, who had a gastric ulcer, was seized with hæmatemesis whilst under ether. It was thought advisable to suspend the operation at the time; but as a subsequent attack took place the patient was again anæsthetised, the stomach opened, and the ulcer successfully ligatured.

[2] *Brit. Med. Journ.*, 1st Oct. 1898. Dr. Drummond also gives other references bearing upon the subject. See also a case reported by the late Mr. Lawson Tait (*Birmingham Medical Review*, May 1894).

to such sequelæ after chloroform in anything like an equal proportion of cases. It is an easy matter to attribute undesirable after-effects to "catching cold." In many and perhaps in most of the cases in which the bronchi appear to have been primarily affected it is probable that a simple extension of the catarrhal process has taken place till a patchy broncho-pneumonia has resulted. In seven out of eight of Dr. Drummond's cases the temperature rose at the end of the first twenty-four hours following the operation to 101° or more. In no case was the disease lobar in its type. Fortunately there were post-mortem examinations in the two fatal cases reported by Dr. Drummond, and distinct signs of lobular pneumonia were found. In the six cases which recovered, abdominal operations had been performed, and Dr. Drummond thinks that the presence of a painful abdominal wound may, by its preventing cough and expulsion of mucus, favour the broncho-pneumonic process. In one interesting case of fatal pulmonary œdema which I published,[1] the patient was suffering before the administration from diaphragmatic paralysis; the operation was for appendicitis; and it is in the highest degree probable that the absence of diaphragmatic action led to such a degree of engorgement at the bases of the lungs that fatal œdema resulted. Richardson attributed the "hydrops bronchi" met with in poisoning by chloral, opium, or tobacco to condensation of the aqueous vapour of inspired air within the bronchioles, the condensation being determined by the lowered body temperature. It is questionable, however, whether any such explanation is applicable to the cases here under consideration. There can be no doubt that the inhalation of large volumes of cold ether vapour may of itself be sufficient to excite a local catarrhal effect, and that, provided there be any interference with the free escape of the catarrhal products, a broncho-pneumonic state may follow. In cases in which the disease is of the lobar type the anæsthetic can hardly be held to be in any way responsible. It has been held by some that whenever ether-pneumonia appears there has been an impurity or decomposition-product in the anæsthetic employed; but so far as I am aware there is no

[1] *Lancet*, 19th March 1898, p. 772.

good evidence to support this view. It is to be hoped that further researches will be made in this direction. In the meantime all that can be said is that we have at present very distinct proof that the use of ether, especially for prolonged operations, is liable to be followed by bronchial catarrh or actual broncho-pneumonia.

With regard to the frequency of **renal complications** after ether it is difficult to speak with certainty, owing to the fact that the statements made by those observers who have specially studied this point are very conflicting. Personally, I have never, to my knowledge, met with any case in which such complications have occurred; but it is only fair to say that my opportunities for ascertaining the condition of patients after anæsthesia are very limited. The balance of evidence brought forward by writers upon this point would seem to indicate that there is a greater risk of renal symptoms arising after ether than after chloroform; and that this risk is increased in the case of patients with previously damaged kidneys. At the same time it must be remembered that patients with pre-existing albuminuria are constantly being subjected, in our hospitals and elsewhere, to deep and prolonged ether narcosis without any unfavourable after-effects arising, and that even in those cases in which uræmic symptoms occur, it is often uncertain whether some factor other than the anæsthetic has not been at work. There is, however, very good evidence that in a certain proportion of the cases in which symptoms of renal disorder arise after surgical operations, such symptoms are attributable to ether anæsthesia.

Dastre,[1] Fueter,[2] and Roux[3] have urged the infrequency of these complications. Weir met with after-albuminuria in 9 out of 34 ether administrations, the patients having been free from this symptom prior to the anæsthesia. Wunderlich,[4] who studied 125 cases of ether and chloroform anæsthesia, found albuminuria *less* common after ether than after chloroform in non-albuminuric subjects; whilst in those in whom albuminuria pre-existed, ether augmented the condition. Barensfeld[5] met with two cases of albuminuria (one being very marked

[1] *Op. cit.*
[2] *Klinische und exper. Beobachtungen über die Aether-narkosa*, p. 28.
[3] Julliard, *op. cit.*
[4] *Annals of Surgery*, May 1894, p. 630.
[5] *Year-Book of Treatment*, 1896, p. 174.

in 150 ether administrations to non-albuminuric subjects, and failed to find any increase of albumen in two patients with pre-existing renal symptoms. In 500 non-albuminous subjects to whom ether was given, Butler[1] met with one case of albuminuria; while Kute in 600 such administrations noted six cases. Ogden[2] found that albuminuria appeared in a considerable percentage of etherised patients whose urine was previously non-albuminous. Kemp quotes hospital statistics and brings forward other evidence in support of the frequency of dangerous renal complications after ether, believing that about 5 per cent of ether cases prove fatal from such complications.[3] The most recent clinical work in this direction has been done by Buxton and Levy.[4] These observers find that, comparing the quantity of urine passed in the first twenty-four hours after an operation with the quantity passed in the twenty-four hours before, there is invariably a considerable diminution; but that this diminution, which is in the *water* and not in the solids, is largely dependent upon diet, purgation, etc. They are unable to satisfy themselves that ether, when properly administered, exerts any unfavourable influence upon the kidneys.

Transient **mental and muscular excitement** may arise after ether, and is more particularly liable to do so in hysterical, neurotic, or alcoholic subjects who have been but a short time under the anæsthetic. In very rare instances **mania** and **dementia** have been recorded.[5] Choreiform movements, lasting three weeks, have also been reported.[6]

There is, more particularly in certain subjects, a slight but distinct risk of **cerebral hæmorrhage** occurring during the process of etherisation, and, as a result, hemiplegia may follow. A case of this kind occurred some years ago at the London Hospital[7]; and there is ground for the belief that this accident is not as rare as is generally supposed.

[1] *Gould's Year-Book*, 1897, p. 246.

[2] *Year-Book of Treatment*, 1898, p. 165.

[3] See also *Annals of Surgery*, vol. vi. p. 327; *New Orleans Med. and Surg. Journ.*, 18th Aug. 1887; *Brit. Med. Journ.*, 2nd June 1883, p. 1082; *New York Med. Journ.*, 1st March 1890; *Canadian Practitioner*, Feb. 1888; *Chicago Med. Journ. and Examiner*, May 1888; *Med. Register*, 4th Feb. 1888; *Journ. Amer. Med. Assoc.*, 5th May 1888; *Brit. Med. Journ.*, 11th Nov. 1899, p. 80 (Epitome).

[4] *Brit. Med. Journ.*, 22nd Sept. 1900, p. 833.

[5] See Dr. Savage's paper, *Brit. Med. Journ.*, 3rd December 1887, p. 1199; also *Boston Med. and Surg. Journ.*, August 1889; also *American Journ. Insanity*, Utica, April 1890. For further remarks on the subject see p. 367.

[6] See Dr. Jacob (*Lancet*, 16th October 1879, p. 539).

[7] The patient was a somewhat elderly man. Clover's inhaler was used. Although the history was not forthcoming before the operation, it was eventually ascertained that there had been a previous apoplectic seizure with complete recovery.

Lastly, **jaundice** is stated to have been produced by the administration of ether.[1]

F. ILLUSTRATIVE CASES

In the three following cases, which I have selected from my note-books, as illustrating various points to which reference has been made, the "*close*" system of etherisation was adopted.

Illustrative Case, No. 5.—F., æt. 63. Looks about 52. Grey hair. Not nervous. Good chest expansion. Regular heart-sounds. Pulse not markedly accelerated. Average build—neither thin nor stout. Operation, dilatation of cervix uteri, etc. Duration 40 min. Administration commenced 9.35 A.M. Gas and ether given by Mr Braine's method (p. 404). "Pure methylated ether" used. Operation begun at 9.40. At 9.44 respiration 41 per minute, pulse 70, of good volume, pupils 2 mm. At 10 A.M. (more deeply anæsthetised) pupils 2½ mm., pulse 80, practically no conjunctival reflex. Respiration deep and stertorous throughout. Had to keep lower jaw pressed well forwards. No reflex movement or crowing breathing during operation. Gradually the pupils grew smaller, 1½ or 2 mm. More ether made pupils 3 mm. Less ether brought them back again to smaller size. They were never larger than 3 mm. After anæsthetic withdrawn cough occurred and retching movements. Pulse became fuller than it had been, and 80 per min. Vomiting continued for three hours, and was relieved by 15 gr. of bicarbonate of soda in hot water.

Illustrative Case, No. 6.—Same patient as above. Has been in bed since last operation, six weeks ago. General condition good. Operation 2.30 P.M. Removal of uterus *per vaginam*. Administration lasted 1 hour 50 minutes. Gas and ether as before, but with pure ethylic ether instead of "pure methylated ether." Took gas and ether well. At 2.45 (¼ hour after commencement of inhalation) conjunctival reflex just present, and pupils 2 mm. Snoring breathing due to tongue. Very little mucus. At 3 P.M. I found patient did well with a moderately deep anæsthesia, *i.e.* loud snoring breathing and distinct lid-reflex. At 3.30 lid-reflex present, good respiration and pulse, pupils 2½ mm. Stertor now only present when lower jaw pressed backwards. Pulse 90. 3.31. Uterus removed. 3.40. Brisk lid-reflex, pupils 2 to 3½ mm., quieter breathing, occasional act of deglutition. 3.48. Tendency to clench teeth. 3.52. Pulse 108. 4.10. Operation over. 4.13. A cough. Patient in lithotomy position all the time, but colour always good. She had half portion of mutton chop at 8 A.M., and a little brandy and water at 12 mid-day, *i.e.* 2½ hours before operation. She coughed up a little mucus soon after operation. Much less vomiting than on previous occasion.

[1] See Murchison, *Diseases of the Liver*, 2nd edition, p. 407.

Illustrative Case, No. 7.—F., æt. about 44. Average height, rather thin, florid complexion, grey hair, very good heart-sounds and chest expansion. Operation, abdominal section (exploratory). Administration lasted 1 hour 12 minutes. Gas and ether by method described on p. 407. Seven ounces of pure ethylic ether used. 9.38 A.M. administration commenced. No difficulty. Breathing soon became stertorous. Operation commenced whilst pupils were 4 mm. and slight lid-reflex present. The breathing, which had been stertorous, was quieter from not having kept up a sufficiently free administration. Pupils became larger with incision. A sudden cough now occurred with an attempt at vomiting. This showed that an error had been committed in not keeping the patient deeply enough under. Cough quickly allayed by more ether. 9.51. Deep stertor, pupils 4½ mm., and no lid-reflex. Quick full pulse. Some mucus. 10.12. Pupil 3 mm., with deep regular breathing and no lid-reflex. This pupil was obviously the proper pupil for this case at this juncture. It gradually became smaller. 10.30. Pupil 2 mm., pulse 112, questionable lid-reflex. Less ether made pupil 3 mm., and led to slight lid-reflex and tendency to cough. More ether had opposite effects, causing a *smaller* pupil. 10.50. Operation and administration over. Florid colour. No nausea or vomiting after.

The advantages of ether gradually given with plenty of air from a semi-open or open inhaler are shown in the three following cases:—

Illustrative Case, No. 8.—M., æt. about 37. Thin; feeble; right lung useless; pus coughed up daily; also purulent discharge from old empyema incision; left lung apparently healthy; temperature elevated; quick pulse. One ounce of brandy, with an equal quantity of water, five minutes before administration. A small quantity of A.C.E. mixture given for a minute or two; then ether (Robbins's pure ether) on a semi-open inhaler. No difficulty whatever. Little if any cough. Allowed a little movement occasionally. (I have omitted to note the nature of operation, but I believe a portion of rib was removed.) The patient had been anæsthetised twice before with the A.C.E. mixture, and I was informed his breathing had ceased on each occasion.

Illustrative Case, No. 9.—F., æt. about 52. Stout. Sitting up in bed. Cannot lie down. Has morbus cordis, and is subject to attacks of angina pectoris and cyanosis. Pulse very feeble and irregular at wrist. (Precise nature of cardiac affection not ascertained.) Wheezing sounds at bases of lungs. Anæsthetic required for passive movement of stiff shoulder. Commenced with a small quantity of A.C.E. mixture (two minutes' inhalation) on an open felt cone, and then gave ethylic ether on same inhaler. Very gradual administration. Respiration grew deeper. An occasional cough. Conjunctiva never insensitive, though once nearly so. Colour always good. Pulse improved when under ether. Manipulations of shoulder lasted six minutes. Came round gradually with moaning respiration. No cyanosis. Satisfactory recovery from effects of anæsthetic.

Illustrative Case, No. 10.—Infant, seven weeks old. A rather weakly but not anæmic child. Was at the breast three hours before. Circumcision. Commenced at 9.45 A.M. with Robbins's ether. Administration 15 minutes. Ether dropped on to Skinner's mask. Some crying, lasting 2 or 3 minutes. Mask now kept fairly wet with ether. No cough or prolonged holding of breath. By degrees respiration more regular and of higher pitch. Then quite regular. Arms a trifle rigid. Very slight movement of legs. Operation begun. Trifling reflex movement and crowing breathing. Respiration, as a rule, regular and noisy inspiration and expiration attended by similar sounds. No mucus. Pupils 3 mm. Flaccid. No conjunctival reflex. Pulse full and quick. Face very red. About $\frac{1}{2}$ drachm of ether now added at a time. The following were the indications of "coming round":—Commencing rigidity of arms; hesitating breathing; movement of legs; and then phonation. Quick recovery. No vomiting when I left.

CHAPTER XI

CHLOROFORM

A. APPARATUS AND METHODS OF ADMINISTRATION

SECTION I.—THE ADMINISTRATION OF CHLOROFORM WITH ATMOSPHERIC AIR

R JAMES SIMPSON, to whom we are indebted for the introduc-
on of chloroform as an anæsthetic, first administered the
ug by means of a simple handkerchief arranged in a cup-like
rm. An unmeasured quantity of chloroform, usually about a
achm, was poured into the hollow thus formed, and the
ndkerchief applied to the patient's face. He recommended
at the vapour should be exhibited "powerfully and speedily,"
use his own words,[1] and considered a gradual administra-
on objectionable, owing to the frequent occurrence of in-
nvenient excitement. Subsequently he used a folded cloth
r towel, and he continued to adopt this mode of administra-
on for several years. In 1860, however, he again modified
is procedure, apparently recognising the necessity of providing
r a more free admixture of air with the vapour. He now
dvised that a *single* layer of a towel or handkerchief should
e laid over the patient's nose and mouth, and that the
næsthetic should be added drop by drop. From the time of
impson to the present day chloroform has been the anæsthetic
ar excellence throughout Scotland; and although there are
any Scotch surgeons who still administer it "powerfully and
peedily," there are many others who follow the later teaching
f Simpson and use smaller quantities frequently applied.

[1] *The Works of Sir James Y. Simpson*, vol. ii., Edinburgh, 1871, p. 177.

Snow was the first to draw attention to the fact th[illegible] order to obtain uniform results, and to avoid too concentra[illegible] a vapour, it was advisable to use some plan by which the p[illegible] portions of chloroform vapour and air could be regulated. [illegible] already mentioned (p. 79), he made experiments with differ[illegible] percentages of vapour, and carefully recorded his results.

Snow's inhaler consisted of a double metal cylinder, the outer sp[illegible] containing water, and the inner one serving for the evaporati[illegible] chloroform from bibulous paper arranged in coils. The inner cylin[illegible] which had holes at its upper part for the free admission of air, co[illegible] municated by means of a flexible india-rubber tube with a face-[illegible] containing inspiratory and expiratory valves. The inhaler was contr[illegible] to supply, at about 60° F., and in the ordinary process of inhalati[illegible] about 5 per cent of vapour; but it possessed an arrangement by whi[illegible] more air might be admitted if desired.

In 1849 Snow employed, in a few cases, a bag of kn[illegible] capacity, which could be inflated by bellows, and in this ba[illegible] a measured quantity of chloroform was placed. He so re[illegible] lated the proportions that an atmosphere containing 4 per ce[illegible] of vapour resulted. He found this plan of administrati[illegible] however, somewhat inconvenient, and preferred the inhal[illegible] just described.

Clover agreed with Snow as to the advantages of workin[illegible] with a known percentage of vapour, and for many yea[illegible] successfully administered chloroform upon these lines.

Clover's chloroform apparatus[1] consisted of a bag holding [illegible] cubic inches of air, and connected by a flexible tube to a face-pie[illegible] The bag was charged before use by means of a bellows holding 10[illegible] cubic inches. On its way from the bellows to the bag the air was ma[illegible] to pass through a warm chamber containing chloroform. Thirty [illegible] forty minims of chloroform were added to this chamber, by a graduate[illegible] syringe, for every thousand cubic inches of air pumped through. Th[illegible] would give from $3\frac{1}{2}$ to $4\frac{1}{2}$ per cent of chloroform vapour. The fa[illegible] piece and tube of the apparatus were almost identical with those us[illegible] by Snow.

Working upon the lines of Snow and Clover, Paul Ber[illegible] subsequently came to the same conclusions as these observer[illegible] and administered, by means of special gasometers,[2] defini[illegible] proportions of chloroform vapour and air. Bert's "méth[illegible]

[1] Described in Erichsen's *Science and Art of Surgery*, vol. i., 1877, p. 18[illegible]

[2] See Dastre, *op. cit.* p. 105.

s mélanges titrés" has been already considered (p. 80). A
ımber of operations were performed by M. Péan upon patients
ıæsthetised with the 8 : 100 mixture (= 8 gm. of chloroform :
)O lit. of air, or about one and a half per cent of chloroform
ιpour). It is stated that the excitement period was generally
›sent or but slightly developed; that there was no resistance
ı the part of the patients; and that deep and satisfactory
ıæsthesia was usually produced in seven minutes.

Numerous other inhalers besides those already referred to
ıve been devised; but space will not permit of reference to
ıem. Most of them have one serious objection, viz. that they
›ssess a face-piece intended to accurately fit the face of the
ıtient. There is, however, one inhaler which deserves notice
—that of Dr. Junker.

Junker's inhaler was originally[1] intended by its inventor for the
lministration of "bichloride of methylene." The principle of the
›paratus is simple. Air is
ımped by means of a hand-
:llows and tubes through
ıloroform, and the air,
ırrying with it a varying
ıantity of vapour, is trans-
ıitted to a loosely-fitting
ıce-piece. Fig. 37 shows
ıe original pattern of the
ıhaler.[2] The bottle for the
ıloroform is graduated to
old from 1 to 8 drachms,
ıd having been charged
ith somewhat less than
ıe latter quantity, is sus-
ended by a little hook
om the coat of the administrator. Air is pumped through the
næsthetic by means of the hand-bellows, an india-rubber tube, and a
ng metal tube passing to the bottom of the chloroform bottle. The
ıetal tube is only partly seen in the drawing. The air, laden with
ıloroform vapour, escapes from the bottle by a *short* metal tube at its

FIG. 37.—Junker's Apparatus: original pattern.

[1] See *Med. Times and Gaz.*, 1867, vol. ii. p. 590; and 1860, vol. i. p. 171.

[2] Although Junker's apparatus when carefully used probably lessens the
sk of chloroform narcosis, several deaths have occurred in connection with
s employment. It is not a suitable inhaler for infants or young children,
nless the chloroform be considerably diluted with alcohol. For accounts
f fatal cases see *Brit. Med. Journ.*, 29th Sept. 1888, p. 719; 15th Sept.
888, p. 625; 21st Dec. 1889, p. 140; 31st July 1889, p. 88; 10th June
882, p. 889.

upper part, connected with an india-rubber tube terminating in a fa- piece. The india-rubber tube leading from the bellows to the bottle m be termed the afferent or bellows-tube; that leading from the bottl the face-piece the efferent or face-piece tube. The face-piece is usu made of vulcanite or leather; but latterly a kind of Skinner's ma (Fig. 38) shaped to the face has been introduced, and has the advanta that, in the event of an exception strong vapour being required, ad- tional chloroform may be sprink upon the mask.

FIG. 38.—Flannel Mask for use with Junker's Apparatus.

Vulcanite and leather face-pie should not be furnished with cushions, as they are not inten to fit the face accurately. Whatev form of face-piece be used, it is im- portant, in the event of it adapt itself more or less closely to t features, that fresh air should en and expired air escape, with t utmost freedom. When it is desir to keep up chloroform anæsthe without employing a face-piece, as in certain mouth and nose operat the face-piece is disconnected, and a mouth-tube (Fig. 41) or nasal cathet is adapted to the efferent tube. When the hand-bellows is worked, a will be heard to bubble up through the chloroform. It is import in using the inhaler, to see that the afferent and efferent tubes are attac to the right metal tubes of the bottle. It is also important not to hav more than the proper quantity of chloroform in the bottle, otherwise s of the liquid may possibly gain access to the efferent tube. And las care should be taken lest the bottle containing the chloroform be tilted during the administration.

It has, on more than one occasion, happened that, by an oversi the india-rubber tubes have been adapted to the wrong metal tubes of th bottle containing the chloroform. The result has been that the liq chloroform has been pumped into the face-piece, and in some cases in the nose or mouth of the patient.[1] A somewhat similar accident has been known to occur by the chloroform bottle becoming tilted during the administration. As one or two fatalities have arisen from these accide I thought it worth while to modify the inhaler, with the object not of preventing the possibility of the tubes being wrongly adjusted, but rendering the bottle less likely to become tilted during use. Fig. shows this modification. Air enters as usual through the hand-bellow The afferent india-rubber tube is made much larger than that ordinar used. The efferent tube is contained within the afferent and emer from the latter at right angles immediately above the hand-bellow

[1] Death has resulted in more than one case. On one occasion tracheot became necessary in order to restore respiration after liquid chloroform had gained entrance to the upper air-passages.

rows show the direction of the currents. The air entering the bellows ses along in the afferent tube system and bubbles up, as shown, through chloroform. It then escapes by the efferent system. The stop-k shown in the figure controls h the afferent and efferent es. When it is turned off, bottle may be placed hori-tally, or packed away in a , without any of the chloro-m leaving the bottle. The paratus is conveniently worked, represented in Fig. 40. By s modification there is no sibility of the flexible tubes ng interchanged ; and there is likelihood of the bottle becom- tilted during the administra-n.

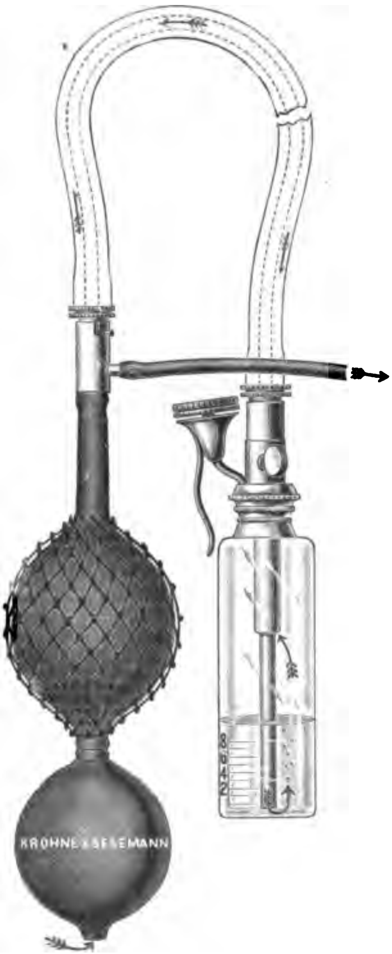


FIG. 39.—The author's Modification of Junker's Apparatus.

Other modifications have been de in this inhaler. In addi-n to the replacement of the lcanite face-piece by the flannel sk, Messrs. Krohne and Sese-nn have interposed in the erent rubber tube a little stop-k ; and when this is nearly sed it offers such obstruction the bellows that a more or s equable chloroform vapour is ntinuously transmitted. These kers have also added a feather the vulcanite face-piece, so at the respiration of the patient y be observed. Dr. Dudley xton[1] has replaced the hand-llows by a foot-bellows, and has ded a little funnel-shaped filling-be to the top of the bottle, so at chloroform may be intro-ced during an administration thout any unscrewing. Mr. rter Braine has devised a bottle ich admits of being placed in y position without the chance of chloroform gaining access to the erent tubes.[2]

It is practically impossible to say what percentage of chloroform

[1] *Op. cit.* p. 113.
[2] *Brit. Med. Journ.*, 25th June 1892, p. 1364.

vapour is usually inhaled from the mask of Junker's apparatus. T percentage will depend upon a variety of circumstances. Foremost a these must be men the quantity of air ta in with each inspira All kinds of brea are met with dur chloroformisation, fr the deep regular res tion of the broad-che and stalwart patien the feeble and al imperceptible breath of the ill-developed fragile child. More respiration may vary amplitude from tim time in the same pat even though the s level of anæsthesia maintained. The most important facto probably the manne which the face-piece or the degree to w air gains admis through it when it adapted accurately to features. Then we take into account the temperature of the chloroform at the time; and this will greatly dep upon the rapidity with which the air is forced through the liq Professor Zengerle of Constanz conducted, at Kappeler's request, interesting experiments on this point.[1] I reproduce his figures.

FIG. 40.—Showing the author's Modification of Junker's Apparatus in actual use.

Experiment.	Compressions of Bellows per Minute.	Quantity of Air supplied.	Chloroform evaporated.
1	120	4 litres	·7 gm.
2	60	2·2 ,,	1·2 ,,
3	40	1·6 ,,	1·4 ,,
4	30	1·2 ,,	1·5 ,,
5	24	1·0 ,,	1·6 ,,
6	20	·9 ,,	1·7 ,,
7	17	·8 ,,	1·7 ,,
8	15	·7 ,,	1·7 ,,

[1] Kappeler's *Anæsthetica*.

e temperature of the chloroform used was 63·5° F. From the experinats it is concluded that *the speed of pumping is in inverse ratio to the rentage of chloroform in the issuing air*—a point of some importance in .ctice. Lastly, the temperature of the room will also exert a slight luence. But, although the percentage of chloroform vapour inhaled ıst vary very widely according to the circumstances mentioned, it may ; be out of place to venture upon the following rough calculation, in ler to obtain an idea of the percentage of vapour inhaled under certain the above circumstances. Given that the respiration of the patient, so as the free access of air is concerned, is unimpeded ; that he breathes the rate of 24 per minute ; that he inhales 540 cubic inches of air per nute (Lister) ; that the bellows of the inhaler is compressed only during :h inspiration, so that all the chloroform vapour is inspired ; and that grain of chloroform produces ·767 of a cubic inch of vapour at 60° F. ıow) ; then, applying Zengerle's table, an atmosphere of 3·5 per cent of loroform vapour will be breathed by the patient. In this calculation is taken for granted that all the chloroform evaporated by each pump the bellows is inhaled. Should the face-piece fit loosely, some would :ape, and the same would occur if the pumping were not accurately ned with inspiration. Under these latter circumstances, the percentage vapour inhaled would be less than 3·5. On the other hand, should e breathing be shallow, and not more than 200 cubic inches of air be spired per minute, a considerably higher, and possibly a dangerous, rcentage of vapour would result.

In using Junker's inhaler the administrator must first see ıat it is in good working order; he should invariably test it efore he commences the administration. Having satisfied imself that it works properly, he should at first hold the .ce-piece at some little distance from the face, and should ently compress the bellows. He will soon see whether his atient can breathe without discomfort the vapour he thus resents to him. The bellows should be compressed during ıe inspiratory phase of breathing. Gradually the face-piece ıould be brought closer to the face. By avoiding jerkiness ı pumping, and by more or less rhythmically compressing the ellows, a tolerably constant chloroform atmosphere may be ıaintained. Rapid pumping, as above pointed out, is open to bjection. When more chloroform seems indicated, the faceiece should be more continuously or more closely applied; rhen less is required, the face-piece must be removed for onger periods, or be only lightly kept over the face.

Junker's apparatus is very useful in operations within or bout the mouth, nose, or pharynx. As already mentioned

(p. 147), it is best in these cases to first secure deep eth[er] anæsthesia, and then to continue with Junker's inhaler wh[en] the patient commences to emerge from the ether narco[sis]. Should the administrator decide on this course, he should g[ive] the chloroform vapour, through the mouth or nose, by mea[ns] of a metal tube or silk catheter attached to the efferent rubbe[r]

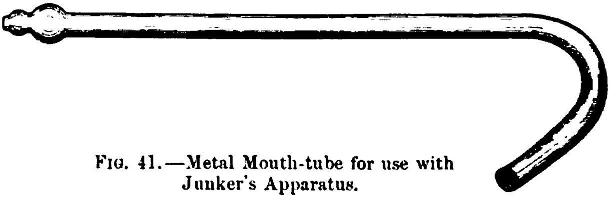


FIG. 41.—Metal Mouth-tube for use with Junker's Apparatus.

tube of the inhaler. I find a silk catheter of great use f[or] passing through the nostril to the back of the phary[nx]. When a mouth-tube is used, that shown in Fig. 41 will [be] found useful. It is made of hard metal, and is of large bo[re]. Tubes made of soft metal, especially if of small bore, are liab[le]

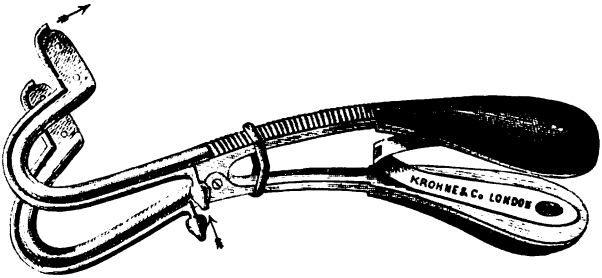


FIG. 42.—The author's Modification of Mason's Gag for use in operations within the Mouth and Nose.

to become so bent that obstruction results. When the mouth is to be used for the introduction of the vapour, I find th[e] arrangement shown in Fig. 42, made for me by Messrs. Krohne and Sesemann, to be useful in some cases. Bent met[al] tubes are brazed to the arms of an ordinary Mason's gag, a[nd] to one of these tubes the india-rubber piping of Junker's apparatus is attached.[1] The chloroform vapour is thus tran[s-]

[1] I described this arrangement in the *Lancet* of 10th Jan. 1891, p. 8[?]: "Remarks on the Administration of Anæsthetics in Oral and Nasal Surgery."

.tted to the back of the throat along the arms of the gag, represented in Fig. 43. It is necessary to remember in ing this arrangement that unless the gag be adjusted far ck in the mouth the chloroform vapour may not reach the rynx in sufficient strength to keep up good anæsthesia, more pecially in patients requiring much chloroform. In those ses in which the surgeon wishes the patient's head to be rned completely upon its side in order that he may operate on the cheek or jaw thus rendered easily available, some

FIG. 43.—Gag of Fig. 42 in position.

lifficulty in keeping a gag in position may be met with. It s obvious, in the first place, that some form of gag is necessary; and, in the second place, that the gag should be upon that side of the mouth which is lying against the pillow. A Mason's gag invariably becomes dislodged in these cases by reason of its arms resting upon the pillow. I have found the gag of Fig. 44 (made for me by Messrs. Weiss and Son) to be useful on these occasions. It should be inserted between the canine or first bicuspid teeth on that side which is to lie upon the pillow. By rotating the wheel at the end, the mouth can be opened to any desired extent, and a mouth or nose tube

used to keep up anæsthesia. In the removal of the upper jaw this arrangement answers well. Another plan is to insert one of the aluminium mouth-props shown in Fig. 13, p. 201 upon the side next the pillow; but this method is open to the objection that the prop may slip. The little appliance of Fig. 45 is very useful when it is particularly necessary to avoid stretching the lips, as in antrum operations. It consists of a solid metal prop, of wedge-shaped form, to which is connected a mouth-tube for the transmission of chloroform vapour from a Junker's inhaler. The surfaces of the prop upon which the teeth rest are covered with lead. The orifice through which the chloroform vapour enters the mouth looks backwards and inwards. Fig. 46 represents the chloroform-prop in position. The stretching of the lips in operations upon the antrum, and the pulling down of the anterior nasal openings in intra-nasal operations are both avoided by this method of anæsthetising.

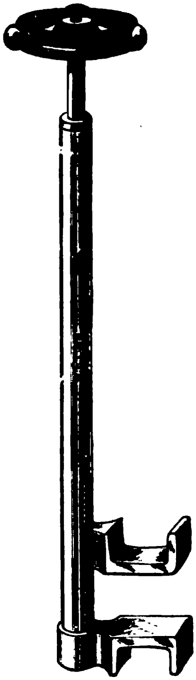


FIG. 44.—The author's Screw-gag for use in certain nose and mouth operations.

Putting aside the special advantages of Junker's apparatus in the surgery of the upper air-passages, what shall be said of this inhaler for general use? We must not lose sight of the important fact that there is no such thing as a perfectly safe appliance for the administration of chloroform, and it is to be regretted that, in consequence of misleading statements to the contrary, there is a widespread notion at the present time that the only way in which chloroform fatalities may be avoided is by the use of a Junker's inhaler. The key to safety in chloroform administration is to be found in a careful study of the effects which this anæsthetic produces in each case, and not in any hard-and-fast lines of procedure. Numerous accidents have occurred, and continue to occur, with Junker's apparatus, conclusively proving what is pointed out in other parts of this work, that patients may die under chloroform

om other causes than too concentrated a vapour. It is true ıat by the regulating methods of administration of Snow, lover, Bert, and Junker, undue concentration of vapour,

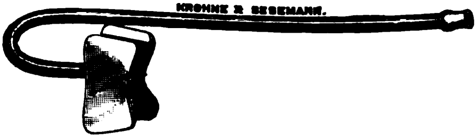


FIG. 45.—The author's Chloroform-prop.

which is undoubtedly one source of danger, may be avoided. But even when, as in using Junker's inhaler, a dilute vapour s presented to a patient, he may, should his respiration be

FIG. 46.—The Chloroform-prop in position.

rapid and deep, absorb in a given time a larger quantity of chloroform than would be taken up when breathing in a slow and shallow manner a much more concentrated vapour.[1] Again, intercurrent asphyxial complications are just as likely to arise with dilute as with strong vapours. Moreover, we meet with patients who display remarkable differences in the quantity of anæsthetic required to produce a given effect,

[1] MacWilliam observed this in his experiments upon lower animals.

so that whilst a Junker's inhaler may supply too strong a vapour for one patient, it may furnish too weak a vapour for another. There are, indeed, many cases in which this apparatus utterly fails[1] to induce deep anæsthesia, such as is now needed in abdominal surgery. And lastly, the use of Junker's inhaler involves a share of attention which might otherwise be devoted to the patient; whilst the constant pumping which is necessary in a protracted administration becomes decidedly irksome. For these and other reasons I have for many years discarded the use of this inhaler, save in oral and nasal surgery.

The question therefore presents itself, What is the best method of chloroform administration[2] for routine use?

Lord Lister, in past years, devoted much attention to the administration of chloroform. Writing in 1861 he recommended: that a common towel, as suggested by Sir James Simpson, should be so folded as to make a square of six layers; that an unmeasured quantity of chloroform, sufficient to moisten a surface the size of the palm of the hand, should be poured upon the towel; that the latter should be brought as close to the nose and mouth of the patient as could be comfortably borne; and that more chloroform should be added from time to time. As Snow had drawn attention to the danger of too concentrated a chloroform vapour, and had from numerous experiments fixed the maximum proportion of chloroform vapour which should be inhaled at 5 per cent. Lord Lister was led to experimentally estimate the percentage of vapour given off from the under surface of a cloth moistened with 1½ drachm of chloroform, and placed immediately above the face. Snow had stated that as much as 9·5 per cent of chloroform vapour might be inhaled from a cloth at 70° F.; but Lord Lister's observations led him to state that the percentage of chloroform vapour breathed from a moistened cloth held close to the face was below 4·5 per cent, and therefore distinctly below the percentage employed by Dr. Snow in his

[1] See for example *Clinical Journal*, 31st March 1898, p. 363.

[2] Of 101 chloroform fatalities collected by Kappeler, 9 occurred with complicated inhalers. Of these 9 deaths, 5 took place during the use of Clover's apparatus. Of the 109 fatalities collected by the English Chloroform Committee, 28 took place with inhalers, and in 5 of these 28 cases Snow's apparatus was being used.

nhaler. Dr. Sansom, writing in 1870,[1] supported Snow in his contentions, and after making experiments, urged that it was possible for a patient, at a temperature of from 60° to 64° F., to inhale an atmosphere containing more than 13 per cent of chloroform vapour, although but one drachm of the anæsthetic had been sprinkled upon lint. When we consider the numerous circumstances which may influence the percentage of vapour nhaled from a cloth moistened with chloroform, we cannot help receiving with some hesitation any statements made as to the percentage breathed in actual practice. This is indeed the weak point in the administration of chloroform from a folded towel. It is true that the risk of too concentrated a vapour may be greatly reduced by providing for the free access of air; but should this precaution be not continuously borne in mind, difficulties may arise. As Lord Lister has pointed out, a large surface moistened with chloroform, such as that which may be presented to the patient when employing a folded towel, handkerchief, or large piece of lint, will supply a much higher percentage of chloroform in the inspired air than a smaller surface. This consideration seems to have led him, in later years, to use the corner of a towel drawn through a safety-pin (Fig. 50, p. 327), or otherwise constricted at a point a few inches from the corner itself, in preference to a folded towel or piece of lint. By using the corner of a towel in this way, a concave mask, suitable to the size of the patient, is formed, and the anæsthetic is added in small, but not too small, quantities at a time. In this way the greater part of the mask becomes saturated, and the moist condition is maintained till anæsthesia is produced. The little mask or cap should extend from the root of the nose to the point of the chin. It differs in no material point from Skinner's or Esmarch's mask of open shape. From calculations which Lord Lister has made, he estimates the volume percentage of chloroform inhaled to be about 1·2—a smaller percentage of chloroform vapour than that which he calculated was inhaled when he adopted the folded cloth for administering the anæsthetic.

Taking everything into consideration, we may say that chloroform is best administered by means of a Skinner's mask and drop-bottle.

[1] *Med. Times and Gaz.* vol. i., 1870, p. 436.

Skinner's mask (Fig. 47) has the advantage of retaining its shape somewhat better than a mask made from lint or towel. It should be covered with a single layer[1] of domett, and should have a wide opening for the nose and mouth in order to permit plenty of air to gain access to the patient. Fig. 48 shows the way in which the mask should be held, and the patient's head adjusted.[2]

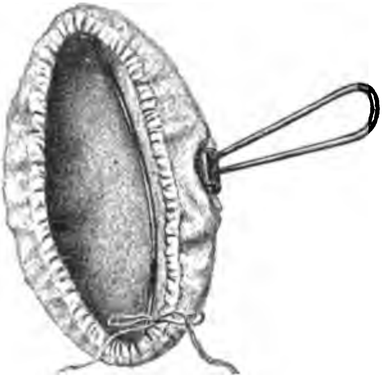


Fig. 47.—Skinner's Mask.

If **lint** be used, the best plan is to take a piece 11 inches long and 7 inches wide, to fold it once over so that the double layer measures 7 inches by 5½, to pinch up between the fingers the free double edge opposite to the folded edge, and to run a safety-pin through the pinched-up portion so that a concave and fan-shaped mask is formed (Fig. 49).

Fig. 48.—Chloroformisation by means of Skinner's Mask.

[1] Dr. Stanley Tresidder of New South Wales has informed me that he finds it impossible to anæsthetise patients with a Skinner's mask having *one* layer of flannel. This is probably due to the higher temperature of the climate. The average summer temperature is about 90° F. He finds it necessary to have two layers of thick flannel on the Skinner's mask.

[2] The little bottle-rest shown in the figure is made for me by Messrs. Mayer

A **corner of a towel** drawn through a safety-pin, as recommended by rd Lister, also makes an excellent little mask (Fig. 50).

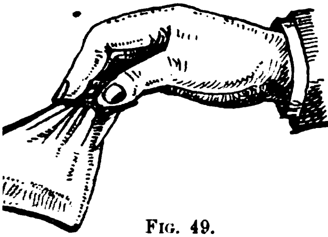


FIG. 49.

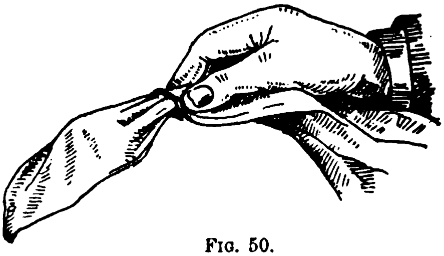


FIG. 50.

The **drop-bottle** (known as Thomas's) (Fig. 51) will be found to be ery convenient in practice.[1] It has a capacity of 2 oz., and is graduated from above downwards. There is a spring valve stopper (Fig. 52), which is worked by the forefinger of the administrator. By a very simple contrivance this spring valve or stopper may be arranged in either of three positions. It may be arranged (*a*) so that no chloroform whatever escapes, even though pressure be made on the button, or the bottle be turned upside down; (*b*) so that chloroform escapes, but only during the time that the button is being pressed down; or (*c*), so that, by simply tilting the bottle, chloroform flows out in a steady and small but not a fitful stream, no pressure upon the button being necessary. The first position is the proper one when the bottle is not in use. The third position will be found very convenient during a lengthy administration.

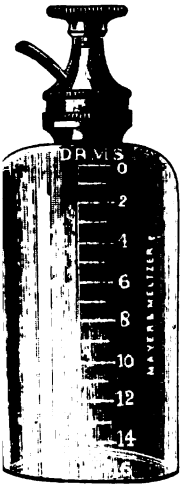


FIG. 51.—Thomas's Drop-bottle.

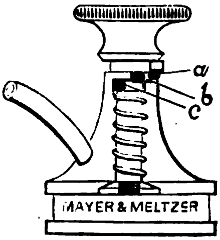


FIG. 52.—Section of Spring Stopper of Thomas's Drop-bottle, showing the three positions in which the stopper may be arranged.

In using the drop-bottle and one of the masks above recommended, we should, in the first place, present to the patient a

and Meltzer. It consists of a flat piece of wood which can be inserted under the pillow, and the projecting end is furnished with a metal holder for the Thomas's drop-bottle. I find this arrangement very useful in hospital practice.

[1] This drop-bottle is made by Messrs. Mayer and Meltzer. The additional slot (Fig. 52, *c*) was suggested by Dr. Sheppard.

very diluted vapour. We have good evidence that the heroic plan already discussed is not unattended by risk. But we must not lose sight of the fact that a too sparing use of chloroform is also open to objection. A few drops should be first administered in order not to alarm the patient by any suffocative sensations. The mask should be gradually brought nearer and nearer to the face. More of the anæsthetic should now be given, so that a distinctly moistened surface results. Any holding of the breath or coughing should be met by a partial withdrawal of the mask. The inhalation should, however, not be wholly discontinued. An endeavour must, in fact, be made to continuously give a well-diluted vapour. The administrator should steer between the two extremes, the rapid and the slow plans of administration. In patients requiring large quantities of the anæsthetic, it may be necessary to keep the mask quite moist, at all events for the major portion of the administration. I have found that by using the Skinner's mask and drop-bottle described, about $1\frac{1}{2}$ to 2 oz. of chloroform per hour are consumed by adult subjects, *i.e.* about 1 drachm every four or five minutes. Children and weakly patients require less than this; whilst in the case of alcoholic persons, etc., more will be needed. The average given is that for the first hour. Less will be required for the second, and less again for the third, should the operation be of this duration.

Dr. Kirk[1] has drawn attention to the bad practice of wholly withdrawing chloroform after once the administration has been started, *i.e.* of administering it in an intermittent fashion; and he attributes many of the chloroform fatalities which have been recorded to this error. He puts forward a theory to explain the clinical phenomena which he has observed. He believes that the withdrawal of chloroform during partial anæsthesia leads to a "rebound" of the circulation which terminates in syncope; but the facts upon which he bases his views are so meagre that we are hardly justified in arguing from them. Moreover, the fatal cases which he has selected to support his theory are, to my mind, capable of being equally well explained on more probable grounds. An inter-

[1] *A New Theory of Chloroform Syncope*, by Dr. R. Kirk. See also a review of the book in the *Brit. Med. Journ.*, 21st March 1891, p. 649.

mittent and sparing administration of chloroform is undoubtedly objectionable, and possibly dangerous in some cases. When chloroform is given in very small doses, swallowing, holding the breath, and exhaustion from struggling, coughing, and vomiting are all liable to arise, and the asphyxiated state thus induced may, as we know, prove a source of danger. All such phenomena are avoided by a more liberal use of the drug.

Chloroform may be administered to children **during sleep.**[1] I have adopted this course on several occasions with satisfactory results (see p. 197).

Section II.—The Administration of Chloroform with Oxygen

This plan of chloroformisation was introduced by Neudorfer of Vienna, who is stated to have excluded all air during the administration, and to have given the mixed oxygen and chloroform vapour by means of a tightly-fitting face-piece.[2] Neudorfer's method has been simplified by employing a Junker's inhaler, to the hand-bellows of which a bag containing oxygen is fixed, so that this gas instead of atmospheric air is pumped through the chloroform on its way to the face-piece. Conflicting statements prevail as to the results of this method. I have had no personal experience with it, as it seems to me to offer no special advantages.

B. THE EFFECTS PRODUCED BY THE ADMINISTRATION OF CHLOROFORM

The phenomena of chloroform anæsthesia are in their *main* features so similar to those which have been already described as characterising the use of ether, that it will probably be better to compare the former with the latter than to specially

[1] See *Lancet*, vol. ii., 1872, pp. 514, 549. See also a letter from Dr. John G. Marshall in *Lancet*, 24th April 1886.

[2] See *Brit. Med. Journ.*, 25th January 1896; *Central. f. Chir.* No. 35, 1887; *Central. f. klin. Med.* No. 35, 1888; *Colonial Med. Journ.*, June 1896.

describe the phases through which the patient passes while inhaling chloroform.

First Degree or Stage.—The vapour of chloroform is more pleasant to inhale than that of ether. When given with a copious supply of air, the sense of suffocation, which is not unfrequently complained of with ether, is reduced to a minimum. Swallowing, coughing, holding the breath, etc., symptoms which almost invariably attend the administration of ether by the semi-open method, are rarely observed with chloroform. In other respects the initial phenomena are identical in the two cases.

Second Degree or Stage.—If we compare semi-open methods of etherisation with open methods of chloroformisation, we may say that mental and muscular excitement are somewhat more common with the former than with the latter. But if we compare the open mode of administering chloroform with the usual (close) plan of exhibiting ether, we may unhesitatingly state that ether has very great advantages over chloroform in this direction. Shouting, gesticulation, screaming, etc., are all more common under chloroform than under ether, provided the latter be properly administered by means of a close inhaler. Muscular and alcoholic subjects, as well as hysterical and excitable patients, may give a little trouble during the period of rigidity, not only by incoherently gesticulating and attempting to rise into the sitting posture, but by holding the breath, moving the arms and legs, etc. Prolonged tonic spasm should make the administrator cautious, and though he need not, as a rule, wholly discontinue the administration, he should not too rashly push the drug. An occasional breath of fresh air must be allowed, and the inhalation entirely suspended for a few moments should any clonic movements appear. The fine tremor which is occasionally met with under ether (see p. 289) is rarely if ever met with under chloroform. The frequency of temporary respiratory embarrassment in vigorous patients under chloroform probably helps to explain the comparative frequency of fatalities in such patients early in the administration. A continuous and yet not too sparing an inhalation, with the careful avoidance of that strength of vapour which might cause "holding of the breath," will, in

st cases, ensure an absence of inconvenient struggling and npered breathing. There can be no doubt that when all muscles of the body are contracted and the respiratory vements for the moment suspended, the right heart is some-at over-full, and air is needed in order to allow of that free lmonary circulation which is essential for the escape of the prisoned blood to the left cavities. In this way the irregular eathing which marks the second stage in certain subjects sses quietly and satisfactorily away, and leaves a snoring rm of respiration which indicates the approach or actual esence of the third stage of anæsthetisation.

It occasionally happens, however, that instead of the spiration undergoing the usual changes here described, it comes inaudible and almost imperceptible. There can be no ubt that, as a general rule, this kind of breathing is the sult of too cautious and too sparing a use of the anæsthetic; id that by a bolder administration (see p. 328) it may be oviated. Should this unsatisfactory form of breathing once ecome well established, the administrator may have some ifficulty in getting out of the dilemma which he himself has reated. The shallow movements prevent a free entrance of ne vapour, and the advent of true anæsthesia is thereby de-ayed. So far as my own experience goes, I am inclined to egard the shallow breathing (which is not unfrequently ssociated with some pallor and feebleness or slowness of pulse) s an indication, at all events in many cases, of a tendency to omit, although others place a different interpretation upon it. f the administration be carefully continued, the symptoms nay often be dispelled, and vomiting averted: the breathing vill become deeper, and the colour and pulse better. Some-imes, however, it is difficult or impossible to get the patient out of this condition without vomiting occurring. Should the næsthetic be entirely withheld, the latter event will be very liable to take place, and, after retching movements have sub-sided, the colour will return, and no further trouble will be experienced.

Certain types of subjects seem particularly prone to pass into a state of false anæsthesia—that is to say, although surgical narcosis has not yet become established, they present such

indications of its presence that the most skilled anæsthetist may be deceived. This is notably the case with children, but false anæsthesia may also be met with in adults. The cornea may be insensitive, the pupils more or less contracted, the breathing quiet and regular; but immediately an incision is made, a considerable reflex movement may take place, and, curiously enough, the corneal reflex may simultaneously reappear (p. 57). One is very liable to fall into this error when the operation is not begun for a considerable time after the signs of anæsthesia have appeared.

In some instances loud palatal stertor comes on early in the second stage, and should be disregarded, as it does not indicate the profound anæsthesia which it might suggest. In others, the respiration is very deep and hurried throughout, but such cases are exceptional.

The behaviour of the circulation will depend upon many circumstances. In most cases there is a tendency, as surgical anæsthesia approaches, for the initial acceleration of the pulse to gradually subside, and for a soft regular pulse of about the normal rate to become established. Any marked interference with free respiration, such as that which would arise from tonic spasm of the respiratory muscles during the period of excitement, reflex laryngeal closure, etc., will very quickly and markedly modify the rate, regularity, and fulness of the pulse. The swallowing, coughing, retching, and vomiting, which are prone to arise when chloroform is improperly administered, are one and all similarly liable to interfere with cardiac action. As nothing is so favourable to the occurrence of these symptoms as an intermittent and sparing use of the anæsthetic, we can readily understand the occasional existence of a feeble pulse comparatively early in chloroform administration. The half-asphyxiated condition into which a patient passes when his air-way is intermittently occluded, or rendered temporarily useless for respiratory purposes in consequence of muscular spasm, rapidly tends to embarrass the heart's action during the inhalation of chloroform. As already mentioned, there is not nearly the same liability to these results under ether. In studying the effects of anæsthetics, and more particularly those of chloroform, one cannot help being struck by the fact that

bleness of the radial pulse is often directly and mechanically pendent upon feebleness of respiration. Other things being ual, a patient whose upper air-passages are perfectly free ll be more liable to pass into a state of tranquil breathing an a patient with, let us suppose, a nasal catarrh. In the mer case, indeed, the respiratory movements may be so allow that they cannot possibly favour pulmonary circula-n, so that the left side of the heart receives comparatively tle blood. In the latter case the slightly obstructed breath-g involves increased respiratory action, and this in its turn so favourable to pulmonary circulation that a full pulse d good colour may be observed. I am now speaking of nditions associated with corneal reflex, not of states of loroform toxæmia. In actual practice I find it a good plan, hen early shallow breathing manifests itself, to artificially duce *slight* snoring by gently pressing the lower jaw back-ards—a procedure which has the effect of increasing respira-ry movements, and consequently circulation.

The pupils during this part of the administration are, as a neral rule, mobile and more or less dilated. They react uggishly, or possibly not at all, to light. As the third stage anæsthesia approaches they usually show a marked tendency become smaller and more fixed. I find in Dr. Sheppard's otes 53 cases in which the pupil was observed before full loroform anæsthesia was established. In 26 it was "moderately ilated" or "dilated"; in 15 "moderately contracted"; and in 2 "contracted."

The ocular globes may, as the result of tonic or clonic pasm, move in this or that direction, or nystagmus may be resent. According to Warner, the movements in this stage re always co-ordinate. Dastre states that somewhat later he globes may follow a light passed backwards and forwards efore them.

Third Degree or Stage.—The phenomena of deep surgical næsthesia under chloroform, when uncomplicated and satis-actorily developed, are very similar to those which have been lescribed as occurring with ether. There are, however, certain emarkable differences.

The **respiration** is usually regular, softly snoring, and some-

what quicker and deeper than normal.[1] Generally speaking more of the anæsthetic will produce a louder stertor, and less will lead to quieter breathing. In some cases there is loud stertor, whilst in others the respiration, though satisfactorily performed, is almost or wholly inaudible. Plethoric, flabby and stout subjects are more liable to stertor than others, and in these especially the jaw may have to be kept pushed well forwards in order to maintain free respiration (see p. 444). There is, however, with chloroform not quite so great a tendency to rigidity of the masseters and adjacent muscles as there is with ether, and it is therefore less common to have to keep the jaw forwards during the administration. The respiratory movements under chloroform are not, as a rule, so deep, so quick, or so noticeable as those met with under ether; and hence some doubt may occasionally be felt as to the efficiency of the breathing. A crowing laryngeal sound is prone to accompany inspiration in some cases. This sound has already been discussed (p. 46). Looked at from all points of view, the respiration during deep chloroform anæsthesia, though favourable by reason of its comparative tranquillity to the performance of many operations, is not as satisfactory as the respiration under ether. Whilst the breathing of the patient under chloroform is occasionally difficult of appreciation, that of a patient under ether is always obvious to the administrator, usually distinctly audible, and a never-failing guide in case of doubt.

Much discussion has arisen concerning the **circulation** in deep chloroformisation. Those who have been accustomed to the excited cardiac action, the bounding and somewhat accelerated pulse, and the general vascular fulness[2] of etherisation, will be struck by the comparatively sluggish circulation of the patient under chloroform. That the heart's action under the latter anæsthetic is in most cases sufficiently well maintained

[1] All varieties of respiration may be met with. I have, for example, notes of a case in which, during deep anæsthesia for an abdominal section, the patient —a female aged forty-two, of average appearance—breathed at the rate of 62 per minute.

[2] Surgeons who have for many years operated under chloroform often bear excellent testimony to the more vigorous circulation of ether, in their complaints as to the greater vascularity when operating under the latter agent.

ere can be no doubt. When the administration has been nducted in the proper manner, and temporary cardiac depres- n consequent upon too sparing a use of chloroform, or upon spiratory embarrassment, has been avoided, the administrator ll find that the pulse becomes slower and steadier than it was ring the first and second stages, and that it settles down to out the normal rate, or even less than this.[1] It is not un- ual to find the almost imperceptible pulse of a feeble subject ow markedly stronger under the finger as surgical anæsthesia proaches. Dr. Leonard Hill finds that his "sphygmometer" dicates a rapid and persistent fall of blood-pressure to the tent of about $\frac{1}{3}$ or $\frac{1}{5}$ of the normal.

During deep chloroform anæsthesia the **eyeballs** are either xed, or one may be fixed whilst the other slowly moves, or oth may slowly move. The loss of associated movements was ointed out by Dr. F. Warner[2] in 1877, and generally indi- ates a considerable and proper depth of narcosis. I have, owever, met with a case in which, even though the patient as deeply and properly anæsthetised, co-ordinated movements ersisted. The eyeballs, if fixed, are usually in the horizontal lane.

The **pupil** during the stage of surgical anæsthesia under hloroform has given rise to much comment, and is well worthy f careful study. Budin and Coyne were the first to direct articular attention to the pupil as a guide. All observers gree that it is usually contracted in deep chloroform anæsthesia, ut the term "moderately contracted" seems to me to be more

[1] An abnormally slow pulse may point to an unnecessarily deep anæsthesia. I have frequently found that when the pulse is very slow less of the anæsthetic will increase its rate. A normally slow pulse will still be slow during deep anæsthesia. I have known a pulse of 46 per min. throughout the administration, the patient, a woman of 75 years, normally possessing a slow pulse. In 20 patients in whom Kappeler compared the pulse of deep chloroform anæsthesia with that observed a few hours before the administration when the patient was not excited, he found a diminution in rate of from 4 to 30 beats per min. Thus, in a child of 12, a pulse of 80 fell to 50; in a man of 60, a pulse of 60 fell to 52; and in a man of 56, a pulse of 72 fell to 48. I must refer the reader to Kappeler's book for sphygmographic tracings of the pulse under chloroform. The Glasgow Anæsthetics Committee of the British Medical Association found that of 50 cases in which chloroform was given for surgical operations, 5 presented a pulse of 64, 7 of 60, 5 of 56, and 1 of 48 during deep anæsthesia (*Brit. Med. Journ.*, 18th Dec. 1880, p. 958).

[2] *Brit. Med. Journ.*, 10th March 1877, p. 292.

appropriate. By taking measurements with a pupillometer,[1] I find that in most cases the pupil measures from 2 to 3 mm. in diameter, usually being about 2½ mm. The average chloroform pupil is therefore decidedly smaller than the average ether pupil. The two resemble one another, however, in that they behave in a similar manner in response to an increase or decrease in the quantity of the anæsthetic given, and in that they are similarly affected by light and other stimuli. As will be pointed out below, the pupil is often of great service as a guide in chloroform administration. Occasionally, as with ether, it remains widely dilated throughout this stage, even though the anæsthetic has not been pushed too far. This is often the case during operations upon cervical glands. A very small pupil (1 or 1½ mm.) in most cases indicates a light anæsthesia; whilst a somewhat dilated pupil (3½ to 4½ mm.) usually means either that the anæsthesia is very profound, or more probably that the dilatation is of reflex origin, and is associated with a light anæsthesia. As already stated when dealing with ether, very little reliance is to be placed upon the pupil as a guide until after the operation has been in progress some little while, and until the administrator has satisfied himself as to its behaviour with more and less of the anæsthetic.[2]

The **lid-reflex** should, as a general rule, be absent. There are, of course, exceptions to this rule, but the third degree of anæsthesia cannot, generally speaking, be said to be present when this reflex phenomenon can be elicited.

The **muscular system** is completely relaxed under chloroform. With ether a slight degree of rigidity may persist for some time, even though the anæsthetic be very freely used; but with chloroform this is very rarely the case.

The normal **colour of the face** is usually at first somewhat

[1] I have used Mr. Edgar Browne's pupillometer in these observations. See *Brit. Med. Journ.* vol. ii., 1886, p. 24.

[2] For further information see an interesting article in the *Lancet*, vol. i. 1875, p. 550. Also a paper by Dr. H. J. Neilson, *Brit. Med. Journ.*, 30th July and 1st Oct. 1887. I cannot agree with Dr. Neilson's contention that when the pupil is strongly contracted and immobile, no chloroform should be given until it begins to dilate again. A very small pupil is, I believe, almost invariably indicative of a light form of anæsthesia, and in most cases denotes the need for slightly increasing the chloroform.

ɔightened, provided that conditions capable of leading to rculatory depression or to obstructed breathing be absent. ɪould the patient be allowed to come out of a deep anæsthesia, ɪllor indicative of the approach of retching may result. Or ɪould an inadequate nasal or oral air-way exist, from pursing p of the lips or other causes, a slight degree of cyanosis would ɛsult. As much more air is admitted with chloroform than ith ether, there is as a rule less duskiness of the features. .fter deep anæsthesia has been established for a short time ɪere is a tendency for the face to become paler than normal, ɑd this tendency persists for the remainder of the administra- .on, unless abnormally deep breathing, coughing, or vomiting ɪould occur.

Mucus and **saliva** are rarely secreted in sufficient quantities ɔ attract attention. The excessive secretion of these fluids rhich occurs in florid young patients under ether is rarely if ver observed under chloroform.

The **temperature**, according to Kappeler, who has made ɑany observations on this subject, is invariably reduced during he administration of chloroform. In thirty cases in which perations were performed the reduction varied from 0·02° C. o 1·1° C., the average being 0·59° C.

The Chloroformisation of Infants.—The upper air- ɔassages of these subjects are so sensitive that the administra- ion of an anæsthetic vapour, even though carefully conducted, ɡenerally causes the breath to be "held" both before and ɪfter unconsciousness. Should crying occur, a rapid intake of ɪnæsthetic will ensue, and care must be exercised when em- ɔloying chloroform to allow a very free admixture of air luring this stage. It is a good plan, in fact, to withdraw the ɔhloroform altogether directly the crying *begins* to show signs ɔf abatement. If the administration be conducted without thus anticipating an excessive intake, an unnecessary, or even ɪ dangerous, degree of anæsthesia may ensue. Guthrie[1] points ɔut that after the crying stage infants often pass into chloro- form "sleep," with contracted pupils, convergent eyeballs, insensitive corneæ, and flaccid limbs. This false anæsthesia (*vide supra*) has been already alluded to. It is best treated

[1] *Clinical Journ.*, 7th April 1897, p. 377.

by briskly rubbing the lips, or otherwise stimulating the infant to deeper respiration; or it may be advisable to add a little ether to the mask, when an immediate improvement in respiration and pulse will ensue. The peripheral circulation of infants is often difficult of appreciation under chloroform especially if the extremities be normally cold. It is important however, to keep a finger upon the radial pulse in all cases in which there is any doubt as to the depth of anæsthesia. I have frequently found the circulation to be a valuable guide especially in hare-lip and cleft-palate cases. In addition to the pulse quickly showing evidences of depression when too much chloroform is given, it also soon becomes feeble, or disappears, as the result of embarrassed or arrested breathing.

C. THE VARIOUS FACTORS WHICH MAY INDIVIDUALLY OR COLLECTIVELY LEAD TO DANGEROUS OR FATAL SYMPTOMS DURING CHLOROFORMISATION; THE DIFFERENT MODES OF DEATH UNDER CHLOROFORM; AND THE POST-MORTEM APPEARANCES

We have, in preceding pages, discussed what I have ventured to term the experimental physiology of chloroform anæsthesia, and have considered, in some detail, the effects produced upon the mammalian organism by toxic quantities of this anæsthetic. We have now to study the numerous clinical facts which may throw light upon the important problem of how and why chloroform accidents occur, and to see to what extent these facts harmonise with those to which attention has already been directed. At the first blush it might seem that we possess, in the vast number of physiological researches which have been conducted, a key to the correct interpretation and understanding of all the chloroform accidents of practice. But this is not so. It is of paramount importance, if we wish to obtain a clear insight into the various modes of onset of dangerous or fatal symptoms during the use of chloroform in surgical practice, that we should bear in mind that, *in a large proportion of accidents, overdosage, in the usual sense of the term*

is conspicuously absent. It would, of course, be wrong to ignore the influence or to minimise the risks of the presence within the circulation of dangerous quantities of this anæsthetic. All I would point out in this connection is that we have before us not merely the simple question of chloroform toxæmia, but other questions whose importance is equally as great or even greater.

The Committee appointed by the Royal Medical and Chirurgical Society in 1864, to inquire into the uses and effects of chloroform, collected and analysed 109 fatal cases which occurred in the years 1848-1863 inclusive. Kappeler, in his valuable work on anæsthetics, gives a similar analysis of 101 additional fatalities, which have been recorded in various journals as having taken place in the years 1865-1876 inclusive. As the matter is one of importance, and as Kappeler's work in this direction is not perhaps as widely known in this country as it deserves, I propose to present to the reader a combined analysis of the 210 cases.

An analysis of 210 *chloroform fatalities* (= 109 *collected by the Committee of the Royal Medical and Chirurgical Society, and* 101 *collected by Kappeler*).

(a) *Sex*

Males	150
Females	59
Not stated	1
	210

(b) *Age*

Under 5 years	2
6–15 years	21
16–30 „	49
31–45 „	53
46–60 „	37
Over 60 years	3
Not stated	45
	210

(c) *Nature of Operation*

Amputations	36
Dislocations	16
Removal of tumours	17
Examination of injuries (including putting up of fractures)	9
Operations on male genito-urinary organs	20
Operations on anus, rectum, etc.	11
Operations on female genital organs	5
Operations on eye	16
Hernia	3
Castration	4
For necrosis, excision of bone, etc.	7
Excision of joints	2
Forcible straightening of joints	7
For application of escharotics	8
Plastic operations	6
Ligature of arteries	1
Opening abscesses and sinuses	7
Impaction of fæces	1
For removal of teeth	18
Removal of toe-nail	5
For relief of neuralgia	2
For delirium tremens	2
For maniacal excitement	1
Not stated	6
	210

(d) *Period of Inhalation at which Death occurred*

Under 1 minute	10
1–3 minutes	13
3–5 „	12
6–15 „	33
Over 15 minutes	7
Not stated	135
	210

(e) *Stage of Anæsthesia at which Death occurred*

Commencing to inhale	14
Stage of excitement	30
Incomplete anæsthesia	49
Fully under influence	68
After operation	31
Not stated	18
	210

Or, Before full effects of chloroform	93
During full effects	68
After operation	31
Not stated	18
	210

(f) *Mode of Death*

It is best, perhaps, to keep the two analyses under this heading separate.

Royal Medical and Chirurgical Committee

Syncope	56
Syncope during stage of excitement	6
Died suddenly	6
Died in a fit	10
Pulse and respiration ceased together	9
Failure of respiration (pulse not noted)	6
Failure of respiration (pulse remaining)	2
Not stated	14
	109

Kappeler

Group 1. Imperfectly recorded cases, or cases in which death could not be ascribed directly to chloroform	61
Group 2. Fully reported cases in which death occurred as the immediate result of chloroform	40
	101

Analysis of Group 2

A. Death with primary evidences of circulatory failure (14 fully under and 9 partially under chloroform)	23
B. Cases in which respiration ceased first (10 fully under and 7 partially under chloroform)	17
	40

(g) *Mode of Inhalation*

On handkerchief, towel, napkin, or lint	87
Lint with sponge	5
On sponge	11
With an ether inhaler	2
Snow's inhaler	5
An inhaler	23
Paper bag or cloth cone	3
Skinner's mask	2
A mask	1
Esmarch's mask	5
Metal inhaler with plenty of air	2
Clover's apparatus	5
Not stated	59
	210

The above facts will act as a kind of clinical basis upon which to start our inquiry; and we shall have occasion to refer to certain of them in the following remarks.

It is well known that a large proportion of deaths during chloroform inhalation have taken place quite early in the administration before anæsthesia has become completely established. Of the 210 cases referred to, the period at which death occurred is stated in 75 cases only, *and in 68 of these (i.e. in 90 per cent) the patients died within the first fifteen minutes.* Comte[1] collected 232 deaths under chloroform. In 224 of these the time at which the fatal event occurred was mentioned: and of these 224 deaths, 112 (50 per cent) took place before anæsthesia was complete. I myself find 130 chloroform deaths reported in the *Lancet* and *British Medical Journal* from 1880 to 1889 inclusive; and of these, 54 took place either before the operation or during some short and trivial operation.

The question naturally arises: Why should the early stages of chloroformisation be specially hazardous? In some cases it has seemed as if death has arisen from psychical causes—from apprehension or alarm on the part of the patient whilst inhaling the vapour. In others it has been thought that the contact of chloroform vapour with the mucous membrane of the

[1] Quoted by Julliard, *L'Éther, est-il préférable au Chloroforme?*

respiratory tract has reflexly inhibited cardiac action. In others, again, it has been supposed that chloroform vapour has, by its local action, induced "holding of the breath," laryngeal spasm, or other asphyxial symptoms directly dependent upon the irritant properties of the drug. In a fourth group of cases, fatal syncope is said to have resulted from the commencement of an operation during partial anæsthesia. In a fifth group, the operation has again been held to be responsible, but the fatal phenomena have been primarily respiratory in their nature. In a sixth series, patients have died during the act of vomiting. And lastly, in a highly important class, fatalities have occurred during or immediately after excitement, muscular rigidity, or struggling. It will therefore be convenient to discuss these different groups of cases, in order to clearly grasp the full significance of the fact that death may arise in numerous ways quite early in chloroformisation. But before doing this it is necessary that we should fully appreciate what happens in arrested breathing arising independently of the presence within the circulation of a toxic substance such as chloroform. Sudden spasm of the glottis, for example, will destroy life within a few minutes, the exact duration of the asphyxial phenomena varying according to the special circumstances present. The arrested breathing leads to a stasis of the pulmonary circulation, to over-distension of the right heart, and finally to failure of this organ, partly from its inability to propel blood through the lungs, and partly from poisoning of its muscular substance by the non-oxygenated blood. In patients with a vigorous and normal circulation several minutes may elapse before cardiac action finally ceases; whilst in very feeble persons and in those with valvular and other cardiac affections the heart may fail almost immediately after cessation of breathing. We have seen in a preceding chapter that one of the most important physiological phenomena of chloroform inhalation is cardiac dilatation, and that this dilatation arises independently of all asphyxia, in other words, from the direct action of chloroform upon the heart muscle. Supposing, then, that before the full effects of chloroform have been produced, and whilst corneal reflex is still present, any intercurrent asphyxial state arises, not only do we have to reckon with

pulmonary engorgement, secondary distension of the right heart, and the widespread effects of non-oxygenated blood, but we have an additional factor to deal with, viz. the continuous absorption of the incarcerated anæsthetic within the lungs and the action of this upon the already embarrassed cardiac muscle. It is hence very easy to see that in certain patients a very slight asphyxial strain under chloroform may cause sudden and fatal syncope, and that, even in the most vigorous subjects, death may take place within a minute or two of respiratory arrest.

The Psychical Factor.—Prior to the introduction of anæsthetics it was not an unknown event for death to take place from fright immediately before an operation [1]; and it is quite possible that in a few instances profound psychical disturbance has led to a fatal result during the first few inhalations of chloroform vapour, *i.e.* before the patient has become unconscious. But there is good reason to believe that the frequency of this so-called "fright syncope" at the very outset of chloroformisation has been greatly exaggerated; for there are few, if any, accounts of similar accidents under nitrous oxide or ether. Granting, for the sake of argument, that emotional states may, *per se*, prove fatal during the first two or three breaths of an anæsthetic, it is difficult to see why such fatalities should arise almost exclusively under the agent we are now considering. It is, in fact, in the highest degree probable that in many of the cases of supposed "death from fright under chloroform" the fatal symptoms have arisen during *unconsciousness*, and that influences far more potent than the mental disturbance itself have been at work. Errors as to the precise moment at which consciousness disappears under an anæsthetic are very

[1] An interesting case is recorded by Kappeler (*Anæsthetica*, p. 118). The patient was a man, æt. 40; an amputation had to be performed. He was so feeble that chloroform was not considered advisable; so a pretence was made to administer the agent by means of a cloth, but no chloroform was used. After four inspirations, respiration and circulation suddenly ceased: the man was dead. This case is interesting because it is in the highest degree probable that a similar result would have attended the use of chloroform, and that the death of the patient would have been attributed to the drug. Sir James Simpson refers to a somewhat similar case, in which a patient suddenly expired during the shaving of the groin, preparatory to an operation for hernia. Other instances of the kind might be quoted. See *Sir James Simpson's Works*, vol. ii. p. 144.

ommon. I have, for example, often heard the medical tendant of a patient address to the latter words of comfort r reassurance when to my certain knowledge consciousness as been in abeyance for several minutes, and the patient has een nearly or quite ready for the operation. It is, therefore, y no means improbable that in many of the recorded cases he patients have died whilst absolutely unconscious of their urroundings, *i.e.* in the second rather than in the first degree f anæsthetisation. But we must not lose sight of the ossibility of psychical influences, originating during the concious stage, prejudicially affecting the patient after consciousness has been destroyed. A complicated machine may be set going by a touch; but when once it has been started, it may be impossible to correct any faulty working which may nanifest itself in time to prevent the machine coming to a standstill. So it may be with the half-anæsthetised subject. Emotional influences arising during consciousness may set in action certain respiratory and circulatory mechanisms which may still remain in operation even when all consciousness has been abolished; and these mechanisms may, under certain favourable conditions, bring about complete arrest of breathing, which, in the case of chloroform, may be rapidly followed by cardiac paralysis. It is a matter of everyday experience that highly nervous, emotional, and apprehensive subjects present peculiar and almost characteristic symptoms during and after the induction of anæsthesia; and so profound may be the initial modifications in respiration and circulation that the whole course of the anæsthesia may be altered. It would seem, indeed, that acute mental disquietude, with its concomitant pallor or lividity, its feeble and quick pulse, and its restricted or excessive breathing, introduces into the administration an element which may, especially in patients of certain physical types, lead to the development of dangerous or even fatal symptoms when all consciousness has been annulled by the anæsthetic. With nitrous oxide and with ether psychical disturbances are of practically no importance; but this is not so with chloroform. With the last-named anæsthetic, hampered and suspended breathing is, for reasons elsewhere considered, specially dangerous. We shall probably not be going too far, then, if

we say, in summing up this branch of our subject, that the dread of an impending operation is probably more prone to lead to dangerous or fatal symptoms under chloroform than under other agents; but that such symptoms are to be looked upon as the *indirect* and not the *direct* effect of the patient's mental state.

The Factor of Reflex Cardiac Inhibition from a Concentrated Vapour (?).—Dastre and other French writers have, as we have seen, formulated elaborate theories as to the occurrence of reflex cardiac inhibition from the contact of chloroform with the mucous surfaces of the upper air-passages. But subsequent research has failed to corroborate their views, and there is no good evidence that in man any inhibition from this cause takes place.

The Factor of Intercurrent Asphyxia dependent upon the Direct Effects of Chloroform Vapour.—A strong chloroform vapour may induce "holding the breath," coughing, swallowing, and other symptoms due to the direct local effect of the anæsthetic; and it is quite conceivable that suspension of breathing thus arising may, in certain subjects, be dangerous (*vide infra*). It is highly probable, however, that the chances of accident from this source are very remote. A concentrated atmosphere is objectionable, not so much because of its power of reflexly arresting breathing, but because it may lead to toxic symptoms. As pointed out by Snow, there is no chance of any mixture of chloroform vapour and air inducing asphyxia from an insufficiency of oxygen in the atmosphere breathed; any intercurrent asphyxial state in chloroformisation must be due to interferences with free respiration, either from some occlusion of the air-tract or from some affection of the nervous or muscular mechanism of breathing. In the early stages of administration, asphyxial conditions are usually, if not invariably, of an obstructive character; in the later stages they may be due to central paralysis of respiration.

The Factor of Early Surgical Shock.—It is generally believed that the commencement of a surgical operation during partially-established chloroform anæsthesia is particularly liable to be attended by sudden and fatal cardiac syncope; but this time-honoured doctrine must either be greatly

odified or altogether discarded (see p. 142). It is true ıat sudden death at the moment of, or immediately after, an ıcision or some other painful procedure was not uncommon efore anæsthetics came into use[1]; and, it is, of course, quite onceivable that an operation begun during the administration chloroform, but whilst consciousness is still intact, might, y similarly inflicting pain, lead to fatal shock. But there every reason to believe that when once consciousness has een abolished by chloroform the risk of such a disaster is reatly lessened. As already pointed out (p. 144), reflex ardiac inhibition as the result of surgical procedures may be ıet with not only in light but in deep anæsthesia, but such condition is rarely, if ever, fatal. In man, as in the lower nimals, the pulse may altogether vanish as the immediate esult of an incision or some other surgical measure; but the nhibited heart soon recovers itself. Were deaths caused in his way, they would be far more common than they are; for housands of patients are annually operated upon whilst only artially anæsthetised by chloroform. That there is little or ıo risk from this quarter is further evident from the fact that ertain surgeons prefer to perform certain operations during ight anæsthesia (analgesia). It is, moreover, a matter of ommon observation that in very exhausted patients—the ubjects who might be considered to be eminently liable to eflex cardiac arrest—this analgesic state is often the safest to naintain. A skin incision made during the second stage of hloroformisation almost invariably stimulates respiration, and t may, instead of temporarily depressing or inhibiting cardiac ıction, have the reverse effect and improve the pulse.

The Factor of Intercurrent Asphyxia dependent upon the Surgical Procedure.—We must not forget an important point in discussing the influence of surgical procedures during light anæsthesia. I refer to the possibility of such procedures producing reflex effects upon respiration. This has already been discussed (p. 142), and we have seen that there are several

[1] Curiously enough, a case of this kind occurred in the Edinburgh Infirmary when chloroform was to have been used for the first time by Simpson. To quote Lord Lister's words: "Dr. Simpson being prevented from attending, the operation was commenced without the anæsthetic, and the patient died immediately after the first incision."

ways in which breathing may become suspended as the result of the surgical procedure. With other anæsthetics than chloroform, these reflex arrests of respiration are comparatively unimportant; but with chloroform secondary syncope may easily arise. Sudden death, indeed, is far more likely to take place in this way than as the direct result of cardiac inhibition. A fat, feeble, and senile patient, for example, may, by the performance of an operation during partial anæsthesia, be thrown into a state of reflex muscular rigidity in which the breath is "held" for a longer or shorter time; and although such a condition would not be hazardous in a patient with a vigorous normal heart, it might easily bring about fatal syncope in the type of subject mentioned. It is practically certain that many chloroform accidents[1] have arisen in this way.

The Factor of Vomiting.—As is well known, the act of vomiting may be accompanied by cardiac depression of greater or less severity; and cases are on record in which fatal syncope has thus arisen, during or after chloroformisation.[2] The graver forms, however, of vomiting-syncope appear to be only met with in patients who are at the time in a feeble condition. The more vigorous the patient, the less seems to be the risk of syncope during vomiting. We must remember, however, that the strongest person may be placed in an unfavourable condition, so far as the actual effect of vomiting is concerned, by the faulty and too sparing administration already discussed (p. 331). The half-asphyxiated and feeble state brought about by a faulty method of administration, is probably favourable to the occurrence of vomiting-syncope. Emaciated and exhausted subjects, such, for example, as those suffering from intestinal obstruction, are particularly prone to succumb under chloroform (or indeed any anæsthetic) during an act of vomiting. Vomiting never takes place during very profound anæsthesia. It will therefore either arise in the period preceding or in that following surgical narcosis. When the

[1] This would appear to have been the cause of death in an interesting case which occurred in the hands of Snow. See his work, p. 207.

[2] As an illustrative case see *Brit. Med. Journ.*, 21st July 1888, p. 135, and 14th June 1884, p. 1162. There is also a well-recorded example in the *Lancet*, 3rd March 1900, p. 632.

mach is full of undigested food, a few breaths of chloroform pour may be sufficient to cause this organ to expel its ntents. But whether food is or is not present in the mach, a slow and intermittent administration is particularly ble to induce emesis—a fact which may possibly act as a 1e to some of the chloroform fatalities in which remarkably iall doses of the drug have been used. Symptoms of ipending vomiting may occur during chloroformisation, and t the act of vomiting may never take place. The pallor, eble pulse, dilated pupil, and shallow breathing are hence ten misunderstood, and attributed to the anæsthetic; whereas ey may be, in reality, due to too sparing a use of the iloroform. Whether such symptoms, originally developing association with vomiting, ever end fatally in weakly ersons without the supervention of actual retching or vomiting testify to their nature, is a matter for future inquiry. It quite possible that the syncope referred to by Dr. Kirk p. 328) may be of this kind.

The Factor of Excitement, Struggling, and Tonic r Clonic (Epileptiform) Spasm.—When excitement and truggling are well marked, as they frequently are in alcoholic, iervous, or vigorous subjects, respiration may become embarrassed n the course of the general muscular contraction, and secondary yncope may arise. It is a significant fact that healthy and nuscular patients are more liable than feeble and phlegmatic subjects to display dangerous symptoms during the induction of chloroform anæsthesia. Children, old persons, and those patients who have become weakened by disease, as a rule take chloroform well. In the foregoing analysis of 210 fatal cases of chloroform inhalation it will be seen that one-half of the number occurred in patients between the ages of 16 and 45, *i.e.* during the most vigorous period of life. As will also be seen, men are more prone to succumb under chloroform than women: about two-thirds of the patients were males. The better-developed muscular system of men is probably responsible for this difference. Other things being equal, the greater the vigour of the patient, the greater will be the tendency to the development of muscular spasm, not only of the extremities but also of the respiratory muscles,

masseters, muscles of the floor of the mouth, larynx, and oth parts. It is in this way that chloroform kills the perfec healthy subject; the fatal symptoms arising when the corn are quite sensitive, and the circulation failing before th anæsthetist can re-establish breathing. It was in this w that many of the fatalities recorded by Snow doubtless to place, although a totally different explanation of them was a the time advanced. The "spluttering at the mouth," livid and other indications of impaired respiration were, in fa regarded as signs of primary heart-failure.

It is by no means uncommon for clonic muscular phenome to arise during the second stage of chloroformisation, mor particularly in cases in which the breathing is somewha obstructed by stertor, jaw-spasm, laryngeal closure, etc. In some of the recorded cases of this kind patients are report to have had a "fit," or to have been attacked by "epileptiform convulsions."[1] All clonic phenomena must be careful watched. Sometimes clonic movements affect the arms an cause them to be more or less rhythmically jerked towar the median line of the body. It is probable that this co vulsive movement of the arms should be regarded as a dange signal. So similar are these movements to those met wi a trifle earlier in the administration, during the period o gesticulation and excitement, that the two are liable to b confounded. Whilst irregular and excited movements invar ably call for a steady continuance of the administration, th clonic phenomena referred to, which are apparently due t spasm of the pectoral muscles, strongly indicate the necessit for air. It is probable that these clonic contractions of th pectoral muscles should be regarded as the result of impulse originating in the respiratory centre; the pectorals comin into action as extraordinary muscles of respiration. Owin however, to the arms having become flaccid, the contractio of the pectoral muscles has no effect in increasing thorac expansion. All that such contraction can do is to draw the

[1] See Lord Lister's account of a chloroform fatality (*System of Surg*, vol. iii. 3rd edition, p. 615). In this case the respiration ceased during an epileptiform spasm. A similar condition has been observed under ether (*Br. Med. Journ.*, 2nd May 1885, p. 887).

rms towards the trunk. The jerky movements referred to re most conspicuous when the arms are hanging down on ach side of the operating-table. I have on three occasions nown cessation of respiration under chloroform to be receded by these movements.

When full surgical anæsthesia has become established here is far less chance of intercurrent asphyxia arising than uring the induction period. This is owing to the fact that n the third degree of chloroformisation general muscular elaxation is, as a rule, present, so that it is no longer possible or breathing to become interfered with by muscular spasm. There is, however, a distinct tendency *in certain subjects* for bstructed breathing to occur even in properly-established næsthesia.

The Factor of Laryngeal Closure occurring inde-endently of the Local Action of Chloroform Vapour.—Ve have already studied (p. 46) the circumstances under vhich laryngeal closure may arise during anæsthetisation. In he description of respiratory embarrassment during imperfect therisation (p. 295) it has been stated that laryngeal spasm nder ether rarely, if ever, gives cause for anxiety. The case s different, however, with chloroform. With this anæsthetic nstances are not wanting in which a high-pitched ("crowing") nspiratory stridor is met with, uninfluenced in extreme cases y pushing the lower jaw forwards or by moderate tongue-raction. I have notes of three cases in which forcible traction pon the tongue had to be employed in order to overcome this orm of obstruction. All the three patients were florid young dults in excellent health. Two were females; the other was male patient. Of the two females, one was being operated pon for ruptured perineum (see Illust. Case, No. 35, p. 449), nd the other was just emerging from deep anæsthesia, which ad been maintained for one hour for ovariotomy. The male atient was undergoing an operation for the radical cure of ernia, and had been allowed to emerge to a very slight degree rom deep anæsthesia. Lord Lister has drawn attention to the mportance of recognising laryngeal obstruction under chloro-orm. He states[1] that a falling together or spasm of the

[1] *System of Surgery*, vol. iii. 3rd edition, p. 604.

arytæno-epiglottidean folds not unfrequently takes place, and that almost noiseless obstruction to respiration may thus result. He regards this condition as indicating a dangerous depth of narcosis; and there can be no doubt that when symptoms of laryngeal closure arise they may often be relieved by giving less anæsthetic.[1]

Other Factors which may lead to Occlusion of the Air-tract.—Some patients become dangerously stertorous in deep anæsthesia (see p. 45), whilst in others the presence of mucus, saliva, vomited matters, blood, etc., within the upper air-passages may introduce an asphyxial element into the administration (see pp. 452 *et seq.*).

The Factor of Posture.—This factor has been already fully considered (p. 138).

The Factor of late Surgical Shock.—For remarks on this subject see pp. 143 and 481.

Pathological Factors.—The various pathological states which may favour or determine respiratory or cardiac arrest under chloroform are discussed on pp. 123 and 128.

The Factor of Susceptibility: Idiosyncrasy.—The susceptibility of the particular patient to chloroform is a matter of some importance in any inquiry concerning the supervention of dangerous symptoms. Billroth, Robert, and other competent authorities believe that, as with morphine, iodide of potassium and other drugs, patients may display very marked susceptibility to chloroform, and may thus exhibit toxic symptoms from doses which in the vast majority of cases would have no such deleterious effects. This is quite in accordance with my own experience. In addition to the recognised differences which exist between alcoholic, neurotic, plethoric, and well-developed patients on the one hand, and temperate, placid, anæmic, and feebly-developed persons on the other, one is often surprised by the very large or very small quantity of chloroform, as the case

[1] Dr. Snow does not seem to have recognised this particular danger, though he states (*op. cit.* p. 234) that, at a trial in France, M. Devergie urged that chloroform was capable of causing death by closure of the glottis. See also a pamphlet by Dr. Black, *Chloroform: How shall we ensure Safety in the Administration?* London, 1855. Dr. Black believed that all accidents under chloroform were due to closure of the glottis, but attributed this closure to the pungency of the vapour. More recently Ricord, Yvonneau, and Stanelli have dwelt upon the dangers of epiglottic and laryngeal obstruction under chloroform.

ay be, which some particular patient requires; and, unless
ie administrator take the measure, so to speak, of each patient,
e will be liable, when dealing with an extremely susceptible
ibject, to overstep the boundaries of safety. It is this con-
deration which seems to me to call for the use of some simple
ihaler such as Skinner's, which is capable of supplying
ifferent strengths of vapour. The term "chloroform idio-
yncrasy" has much to be said in its favour when applied to
ases displaying this abnormal susceptibility.

The Factor of Simple Chloroform Toxæmia: Fourth Degree or Stage in the Action of Chloroform.—Simple
hloroform toxæmia may be brought about in several ways.
n the first place, the vapour-percentage of the atmosphere
resented to the patient may be too high (p. 79), so that,
vithin a comparatively short time—the duration varying with
he depth and rate of breathing, the permeability of the air-
ract, the state of the pulmonary circulation, and other con-
litions—signs of an overdose manifest themselves. As already
nentioned, Snow, Clover, the English Chloroform Committee,
ind Paul Bert considered the dangers of chloroformisation to
e distinctly increased by the administration of atmospheres
ontaining more than 4 or 5 per cent of vapour. Snow
alculated that the quantity of chloroform sufficient to stop
espiration in an average adult patient was 36 minims, when
equally diffused through the circulation, and he pointed out
that, supposing the patient to be breathing a 10 per cent
vapour, a considerable part of this amount might enter the
lungs in a few inspirations, for 36 minims of chloroform occupy
37·5 cubic inches, and would be contained in 375 cubic
inches of air, which might be breathed in less than a
minute. In the next place, it is clear that, even with
atmospheres containing less than 4 per cent of vapour, a
dangerous degree of anæsthesia may result, either because of
some special susceptibility on the part of the patient, or
because of the occurrence of such exaggerated breathing that
an abnormally free absorption of vapour ensues.

When studying the experimental physiology of this subject we saw (p. 96) that the usual sequence of events in chloroform toxæmia is (1) progressive fall of blood-pressure; (2) paralytic

failure of respiration; and (3) cessation of the heart's action. But we have also seen that *pari passu* with this fall in tension and respiratory paralysis, a greater or less degree of dilatation of the heart's cavities takes place, so that, although it is perfectly true that with toxic doses respiration fails before the heart finally ceases to beat, we cannot shut our eyes to the fact that for a considerable time before the heart comes to a standstill (the time varying in different cases), it has ceased to act *in a clinical sense, i.e.* as a propeller of blood into the peripheral arterial system. In actual practice an overdose of chloroform may therefore bring about one of three states:—

(*a*) Cessation of breathing whilst the wrist-pulse is still perceptible;

(*b*) Cessation of the wrist-pulse whilst breathing is still proceeding; or

(*c*) Simultaneous cessation of the pulse and respiration.

It might be imagined that two at least of these three clinical states are incompatible with experimental data, but such is not the case. All three are perfectly in harmony with physiological teaching, for *the absence of a wrist-pulse by no means indicates that the heart has ceased to beat.* Clinical observers of Snow's time fell into the error of regarding pulse failure and heart failure as one and the same thing; and it hence happened that many cases in which the heart was still beating, although unable to cause a wrist-pulse, were looked upon as cases of "primary cardiac syncope." We now know that in chloroform toxæmia, pure and simple, respiration ceases before the *heart*, but not necessarily before the *pulse.* It might be, and has been, argued from this that, after all, chloroform is essentially a respiratory poison, and that the circulatory element in the toxæmia should therefore be disregarded. But this is an error which cannot be too strongly condemned, although it has unfortunately received the support of authority. Although it is perfectly true that respiration generally, if not invariably, ceases before the heart muscle is finally paralysed, and that in chloroform administration attention should *primarily* be directed to the respiration, the clinical fact remains that in all threatening or fatal conditions dependent upon simple chloroform toxæmia circulatory depression is the characteristic and dangerous

symptom. Death usually takes place, indeed, not from our inability to restore respiration, but from our helplessness in reinstating cardiac action.

As in the case of ether, the phenomena which depend upon the administration of an overdose of chloroform will be found to be associated with an insensitive cornea. So long as the lid-reflex is present, any dangerous symptoms which the patient may evince must depend upon other causes than simple toxæmia.

The symptoms which *collectively* indicate the supervention of the fourth degree or stage of chloroformisation are: Impairment or complete cessation of respiration; an abnormally slow and feeble pulse, which tends to become irregular and then imperceptible; moderate dilatation of the pupils, increasing in severe cases to wide dilatation; complete absence of lid-reflex; a dusky pallor of the complexion; and a separation of the eyelids, with upturning of the eyes.

Should the administration have been conducted rapidly, recklessly, and without the important precaution of admitting a sufficient quantity of air, the patient may so suddenly die that all attempts on the part of the administrator to recognise the order in which the fatal symptoms have arisen may be completely futile. In such cases as these the pulse may fail before respiration ceases.[1]

But when toxic quantities of chloroform are more gradually given, the symptoms displayed by the patient will be more capable of differentiation and analysis; although the period which elapses before such symptoms culminate in total cessation of respiration and peripheral circulation will still be very short —far shorter indeed than in the case of ether. Obvious impairment of breathing is generally noticeable before thoracic and abdominal movements altogether cease. Most commonly the breathing simply becomes shallow and slow before the final stoppage takes place; but gasping, jerky, or irregular movements may precede the arrest. In some cases inspiration is accompanied by spasmodic retraction of the lower jaw.

Summary.—It is clear from the foregoing considerations

[1] One of the best reported cases illustrating the mode of death from a concentrated chloroform atmosphere is to be found in the *Brit. Med. Journ.*, 25th Oct. 1884, p. 811.

that the two main elements with which we have to reckon in chloroform administration are (1) suspended or embarrassed breathing from whatever cause arising; and (2) simple chloroform toxæmia. Whilst it is true that, in the latter, pulse failure may take place without there being at the moment any noteworthy impairment of breathing (see p. 354), there is, in most chloroform accidents, some initial and apparently trifling interference with free respiration. The characteristic feature of death under chloroform is the rapidity with which the circulatory wheels of the vital machinery are thrown out of gear by the arrest of those of respiration. The dependence of a good circulation upon free respiration must be perfectly obvious to any one who has had experience in anæsthetising. It matters not *how* breathing becomes hampered, the effect will be the same, viz. to produce an asphyxial state during which the circulation will fail with greater or less rapidity. In cases of intercurrent asphyxia dependent upon occlusion of the airway no air reaches the lungs (although futile thoracic and abdominal movements may for a time persist); the elimination of carbonic acid is equally impossible; the imprisoned chloroform vapour within the pulmonary alveoli is absorbed by the pulmonary blood-stream; the right cavities of the heart become more and more distended as the result of the asphyxial state; the heart muscle becomes more and more poisoned by the chloroform-laden blood; the dilatation increases; and, unless air be admitted to the lungs before cardiac embarrassment has gone too far, death will result. Such a death as this may take place within a very short time—that is to say, it may be more or less sudden—or it may be postponed for several minutes. Much will depend upon the pre-existing state of the heart and lungs, and upon the amount of anæsthetic in the blood and air-passages at the moment of arrested breathing. A patient whose heart's action and respiration are both embarrassed in the course of an acute attack of pleuro-pneumonia may, for example, suddenly die under chloroform from the slightest possible interference with the already embarrassed respiration, the pulse vanishing at the wrist during or immediately after the momentarily suspended breathing. On the other hand, a vigorous subject, whose heart and lungs are sound, and whose

respiration becomes obstructed or otherwise suspended before the corneæ have become insensitive, may retain a wrist-pulse for a considerable time before death ensues. Such intercurrent disturbances in breathing as those referred to in the latter case are equally or even more common during the induction of nitrous oxide or ether anæsthesia; but when they arise under these anæsthetics they are not followed by disastrous consequences save in the most exhausted subjects. With chloroform the case is different, for any interference with free respiration is dangerous owing to the powerful effects which the imprisoned anæsthetic rapidly produces upon the heart, already labouring under an asphyxial strain.

Post-mortem Appearances.—These naturally vary considerably, according to the stage of anæsthesia at which death has occurred, the presence or absence of intercurrent asphyxia, the state of the patient's heart and lungs prior to the administration, the nature of the remedial measures adopted, and other circumstances. Thus, in non-asphyxial cases in which the patient dies from an overdose of the drug gradually administered, the heart is usually found flaccid and empty, the lungs crepitant and not markedly engorged, and the brain not congested.[1] In deaths due largely to intercurrent asphyxia, general venous engorgement, distension of the right cavities of the heart, pulmonary congestion, and partial or complete emptiness of the left cardiac chambers will be generally met with. But when death results from some slight asphyxial complication in patients with feeble, fatty, or dilated hearts, or when it takes place in those whose cardiac muscle has become enfeebled by incautious or prolonged chloroformisation, there may be few if any of the ordinary evidences of asphyxia, owing to the right heart failing before any marked distension of its cavities has occurred. Snow states that in numerous lower animals which he killed by chloroform the right cavities of the heart were always found filled with blood, whether they died suddenly or gradually, the left cavities never containing more than a small quantity of this fluid. The Royal Medical and Chirurgical Committee also found in their experiments that, as a general rule, all cavities contained more than the normal quantity of

[1] For typical case see Snow, *op. cit.* p. 170.

blood, but that the right contained more than the left. In the majority of cases the lungs were of a bright florid colour, and in many instances there were sub-pleural ecchymoses. The liver, spleen, and portal system were, as a rule, congested, and the superficial brain vessels contained more blood than usual. It is highly probable that whenever the right heart is found distended, this distension has the same significance as in death from simple mechanical asphyxia—in other words, that it indicates an obstructed pulmonary circulation. It is doubtful whether chloroform, by its local action within the alveoli or by its presence within the pulmonary blood, ever really induces a sufficient degree of pulmonary stasis to account for this distension. It is far more probable that simple impairment or suspension of respiratory action is the chief factor, and that the blood stagnates owing to the cessation of lung-expansion. With regard to the amount of blood found within the lungs after death, Leonard Hill points out that much will depend upon whether respiratory arrest has taken place during inspiration or expiration. He found that if the trachea were clamped at the height of a forcible expiration, there might be only $\frac{1}{60}$th of the weight of the blood of the body in the lungs, whereas, if the clamping were effected during a deep inspiration, there might be as much as $\frac{1}{10}$th. Kunkel[1] states that the heart killed by chloroform always stops in diastole, the contraction of the left ventricle, which has been so often reported, being simply a post-mortem appearance. Guthrie[2] notes that Cooper, Binz, Pritchard, and Berend agree in their statements as to the blood after death under chloroform presenting a peculiar dark cherry colour, and being more fluid than usual. Fränkel[3] states that the kidneys, liver, and heart are found homogeneously altered and their specific elements affected by cloudy swelling (coagulation-necrosis), whilst deposits of pigment are met with in the renal tubules and in the hepatic parenchyma. Ajello[4] also describes degenerative changes in the liver, kidneys, heart, and blood-vessels in four cases of fatal chloroform syncope.

[1] *Handbuch der Toxikologie*, Part I., 1899, p. 449.
[2] *Loc. cit.* [3] *Virchow's Archiv*, 129 (1893), 2 Heft.
[4] *Annals of Surgery*, March 1897.

D. THE DEPTH OF ANÆSTHESIA NECESSARY FOR SURGICAL OPERATIONS

We can readily understand the discrepancies of opinion concerning the effects produced by chloroform when we reflect that administrators of large experience differ widely as to the degree of anæsthesia which they consider to be appropriate for surgical operations. One chloroformist will work with a light, another with a moderately deep, and another with a very deep anæsthesia. The success of Syme in administering chloroform appears to have been principally due to the almost invariable maintenance of a profound narcosis. From what has been already said, the reader will have gathered that the surest way to avoid irregular and hampered breathing (which is liable to be followed by circulatory depression) is to work with that depth of anæsthesia in which such alterations in respiration are impossible. In the early days of chloroform, patients were rarely thoroughly narcotised. Struggling, tonic spasm, holding the breath, retching, vomiting, and other symptoms of imperfect anæsthesia were the rule rather than the exception. The patient was usually placed moderately deeply under chloroform; the operation quickly performed; and in many, if not in most cases, no more of the anæsthetic was administered. In those operations which could not be thus rapidly completed, the patient was allowed to become nearly conscious before more chloroform was given. Simpson, Syme, and Lister have, in their turn, drawn attention to the importance of a more free and uniform exhibition of this agent; and the profession is greatly indebted to these observers for their emphatic teaching. If chloroform is to be given at all, it must not be given too sparingly.

But, as has been before pointed out, the maintenance of a profound narcosis reduces the workable area under chloroform to somewhat narrow limits. In other words, if we wish on the one hand to avoid the dangers of a light anæsthesia, and on the other to keep away from the phenomena of an over-dose, we shall find our task by no means easy. Most of that which has already been said with reference to the maintenance of a

right degree of ether anæsthesia will apply to chloroform; but there are some differences in the two cases which are of considerable importance.

As in the case of ether, the anæsthetist, having once secured a satisfactory form of anæsthesia, must be guided by—

(*a*) The respiration;
(*b*) The occurrence of swallowing movements;
(*c*) The lid-reflex; and
(*d*) The state of the eye and pupil.

But in addition to these guides, experience teaches us that it is advisable to observe—

(*e*) The strength and frequency of the pulse; and
(*f*) The colour of the face and lips.

Finally, cases occasionally occur in which

(*g*) Rigidity of the muscles in various parts of the body (hands, neck, etc.)

may help the administrator in deciding as to the proper level at which he should keep his patient.

(*a*) If one symptom, and one symptom only, is to be taken as a guide during chloroform administration, the **respiration** should undoubtedly be selected. When once a softly snoring form of breathing has been secured, an endeavour should be made to maintain it. The withdrawal of the anæsthetic will lead to tranquil and inaudible respiration; whilst an increased quantity of chloroform will, in most cases, favour the continuance of (or even augment) the existing stertor. I say *in most cases*, because it is sometimes impossible to obtain this desirable state of respiration; and the administrator may be in doubt as to the depth of the narcosis. Should the breathing be inaudible, he may usually cause a softly snoring sound to manifest itself by gently pressing the lower jaw backwards, and this artificially produced stertor will often act as a good guide. Owing to the tendency for tranquil respiration to occur, even when an insensitive conjunctiva, a moderately contracted pupil, and muscular flaccidity are present to testify to the establishment of deep anæsthesia, the administrator will not unfrequently be in a state of doubt as to the degree of narcosis, if he relies solely on the respiration. He will not know whether the quiet breathing indicates a too light or a

too deep anæsthesia; and in the absence of other indications he may therefore erroneously administer too much or too little of the anæsthetic, as the case may be. Fortunately other guides come to the rescue, and by the assistance of an act of deglutition, a smaller pupil, slight lid-reflex, an expiratory noise, or a tendency towards tonic muscular spasm, the administrator becomes aware that the tranquil respiration is indicative of too light an anæsthesia. As a general rule we may say that—

Inaudible breathing,
A good colour,
A moderately contracted or contracted pupil, and
A slight degree of lid-reflex,

collectively indicate the need for more of the anæsthetic; and, as the result of increasing the quantity of chloroform, respiration will quickly become audible and deeper. If the patient should have been allowed to come so far out of a deep anæsthesia that the inaudible breathing is associated with pallor, feeble pulse, and other indications of approaching vomiting, it may be difficult, or even impossible, to secure a deeper and noisier breathing till the vomiting has taken place.

A very deep chloroform anæsthesia is not unfrequently associated with a somewhat shallow and hampered form of breathing; but this, if carefully watched, does not seem to be fraught with any great danger. It may indeed be necessary in certain cases, and in certain subjects, to proceed to this degree, in order to avoid reflex difficulties. The breathing in question is usually associated with the absence of lid-reflex, slight duskiness of the features, and a rather slow regular pulse, which, although not as full as in a less profound anæsthesia, is not markedly feeble. When the patient has passed into this condition the administrator will find that by briskly rubbing the face and lips[1] with a dry towel he can generally

[1] Mr. Meredith, of the Samaritan Hospital, informs me that he used to find this little procedure of great value in the administration of chloroform for abdominal section. The late Dr. C. E. Sheppard also found it of advantage. In consequence of the recommendations of Mr. Meredith and Dr. Sheppard, I have frequently resorted to brisk friction of the lips and cheeks when any tendency towards feeble respiration or circulation has arisen under chloroform; and always with good results. I have often been surprised at the immediate

maintain efficient respiration, and consequently a better pulse and colour.

High-pitched crowing breathing (inspiratory) is of considerable interest in connection with the administration of chloroform. Generally speaking, profound anæsthesia prevents its occurrence. In certain operations, however, it is practically impossible to obviate the laryngeal stridor, even by very large doses. Should it tend to culminate in total cessation of breathing, the best plan is to suspend the anæsthetic and to proceed as recommended on p. 447.

The manner in which expiration is performed will often assist the administrator, and I cannot do better than quote from Dr. Sheppard's notes, in which I find the following interesting remarks:—

> It would be useful and of practical importance to get at the exact series of signs connected with the expirations, as they are of great use in the conduct of many cases. They seem to occur pretty regularly in the following order, as the patient emerges from the deep regular breathing of chloroform narcosis. (1) Slight holding of the breath before the commencement of expiration, soon developing a definite catch. (2) The expiratory catch becoming definitely vocal, but only occurring at the commencement of expiration. (3) Definite expiratory phonation, the vocalisation continuing all through the expiration, or it may still retain the character of (2), and develop into straining. (4) Movements of tongue and lips, etc., producing inarticulate mumbling. (5) Definite articulate phonation.

Cheyne-Stokes breathing, of a more or less typical character, is not uncommon under chloroform, especially in exhausted and senile subjects. Although it is generally met with in profound anæsthesia, I have known it arise when a slight conjunctival reflex was present. I have notes of one case in which it disappeared directly the A.C.E. mixture was substituted for chloroform.

(*b*) All that has been said with regard to the occurrence of **swallowing movements** under ether will apply in the present instance (p. 300).

(*c*) With regard to the **lid-reflex** under chloroform there is little to say in addition to what has been stated when dealing

improvement. I have known almost imperceptible breathing to quickly become deeper and more audible, and have observed this change to be at once followed by a better pulse and colour.

with ether (p. 300). The phenomenon is, perhaps, less trustworthy as a guide under chloroform than under ether. At the same time it certainly ranks amongst the most important of the clinical signs of anæsthesia. In many cases a *trace* of this reflex may be permitted; but there are numerous subjects and numerous operations in which both corneæ must be kept absolutely insensitive throughout, otherwise inconvenient phenomena, such as retching, coughing, and abdominal rigidity, may occur. If, as is taught by some,[1] the inhalation be stopped directly the cornea becomes insensitive, the danger of chloroform toxæmia may of course be largely avoided; but the irregular effects to which such a line of practice must inevitably lead would hardly satisfy the modern exponent of abdominal surgery. It is better, as a rule, when the corneal reflex disappears, to lessen rather than to discontinue the anæsthetic, and by carefully studying other indications, to decide whether or not this reflex may be permitted to return. In robust patients, undergoing operations upon sensitive parts, the lid-reflex should, as a general rule, be kept in abeyance throughout. Old people, feeble subjects, and those who have lost much blood, or have become otherwise exhausted by the operation, may usually be allowed to exhibit lid-reflex occasionally. There are certain operations which are best performed during a moderately deep anæsthesia, such, for example, as those for the removal of tonsils or nasal polypi; and in such cases it is best not to abolish the lid-reflex save for a few seconds at a time.

(*d*) Most of what has been said concerning the value of the **eye and pupil** as guides to the degree of ether anæsthesia will apply to chloroform. As already mentioned, the average chloroform pupil is smaller than the average ether pupil. Like the latter, it is most useful when other signs are equivocal; as, for example, when the breathing is shallow and the lid-reflex absent. Moreover, when from the nature of the operation the breathing is deprived of its usual characters, variations in the size of the pupil in response to more or less of the anæsthetic may be very significant.

The following extract from Dr. Sheppard's notes is worth quoting in this connection:—

[1] See Lawrie, *Lancet*, 14th March 1891.

The dilated pupil is an excellent guide as an indication of returning consciousness, but one must be *very certain* that the patient is recovering and not actually becoming more deeply narcotised. . . . On administering a fresh dose, 5 to 10 minims, of chloroform to a child with the dilated pupil of recovery, the effect is *not immediate*, but after five or six inspirations after cessation of chloroform, the pupil becomes contracted. The postponed operation of chloroform is better seen in this way than in any other. Hence the danger of even 5 minims to a child with the dilated pupil of deep narcosis.

Speaking generally, a dilated pupil *plus* conjunctival reflex calls for more chloroform; whereas a dilated pupil *minus* conjunctival reflex should be taken to mean immediate withdrawal of the anæsthetic till the pupil has become smaller, or the conjunctiva slightly sensitive.

(*e*) Like the pupil, the pulse is of value as a corroborative guide. Some writers, and particularly those of the Scottish school, have laid so much stress upon the importance of *never* feeling the pulse that one is naturally tempted to inquire upon what grounds such teaching is based. It is contended (1) that the whole attention should be directed to the respiration; and (2) that, as the pulse may become feeble immediately prior to vomiting, the anæsthetist may be misled, and suspend the administration, instead of continuing it. It is perfectly true, and even self-evident, that if the administrator's powers of observation are so limited that he cannot trust himself to watch more than *one* sign, that sign should be the respiration. But let us hope that such anæsthetists are rare. It is certainly possible for an administrator of average ability to attend to many other indications than the breathing, without relaxing the almost automatic vigilance which he should obviously bestow upon that function. With reference to the pulse-feebleness, which often marks the approach of vomiting, there is surely no harm in knowing that such feebleness is present (although, as will be pointed out below, pulse indications are of little or no value so long as the cornea is sensitive), nor is there any objection to treating this feebleness, when it is obviously connected with light anæsthesia, by an increase of the anæsthetic. When corneal reflex has been destroyed, and deep anæsthesia produced, the slow, regular pulse of chloroform narcosis generally becomes established, and it is from this

point onwards that the peripheral circulation will afford valuable indications as to the depth of anæsthesia.[1] An exceedingly slow and feeble pulse will, for example, call for less chloroform; and this treatment will soon be followed by better circulation. In rare cases it is impossible to proceed beyond a certain point without inducing an intermittent action of the heart; and such cases must be similarly treated. The administrator should occasionally consult the temporal, facial, or superior coronary pulse.[2] If he can feel a fair pulse in either of the two former arteries, he may depend upon the wrist-pulse being better than he anticipates. I have often been unable to distinguish a temporal pulse, although the radial was at the moment of fair volume. I find the superior coronary pulse to be very accessible during chloroform administration.

One can quite understand the Scotch school and the Hyderabad Commission denying the value of pulse indications, for, according to their views, the administration should not be continued beyond the point at which corneal reflex disappears. I fully admit that if a case can be conducted without destroying this reflex, and if breathing be unembarrassed and free, the pulse may be disregarded, except in cases of impending or actual surgical shock. But, as pointed out above, it is necessary in many cases to conduct the administration without allowing even a trace of lid-reflex to be present; and it is in such cases that the pulse will give valuable indications as to the depth of anæsthesia. The necessity for carefully observing the peripheral circulation in cases of surgical shock is sufficiently obvious.

(*f*) **The colour of the face and lips** is generally of value as a guide, although too much reliance must not be placed upon it *per se* (see p. 336). Thus I have notes of cases in which the wrist-pulse has vanished (from surgical causes) without any marked alteration in colour; and it is a matter of everyday

[1] Snow (*op. cit.* p. 250) found that watching the pulse was of great service, especially when employing unknown strengths of chloroform vapour.

[2] The late Mr. J. Mills, who had a large experience in the administration of anæsthetics (*Lancet*, vol. ii., 1880, p. 912), also directed attention to the advantages of watching the pulse during the administration of chloroform, and quoted three cases illustrating this point.

experience that a good peripheral circulation may coexist with pallor and lividity. A dusky or cyanotic aspect of the face is probably always indicative of deficient blood oxygenation and of the need of more air. Cyanosis in the *extremities* may however, depend upon vascular stasis induced by surgical shock, and may coexist with a fairly florid complexion. Pallor occurring during a light anæsthesia generally means the approach of vomiting; it may, however, result from strictly surgical causes.

E. AFTER-EFFECTS

The after-effects of chloroform differ considerably in different cases; and we are still to a great extent in the dark as to the factors which come into play in their production. The patient who has been kept deeply and properly anæsthetised will usually make a very satisfactory recovery, provided that there be no mechanical interference with the elimination of the anæsthetic. The cough or act of retching, at the termination of the administration, will bring back a good colour to his face and lips, and if left to himself he will probably pass into a quiet sleep. When inadequate quantities of the anæsthetic have been given, so that the patient's respiration has been more or less hampered over a considerable period by swallowing, coughing, straining, vomiting, etc., recovery from the effects of chloroform is not so satisfactory. Pallor is more common; and the pulse may remain feeble for a considerable time. A similarly unsatisfactory recovery is also common when dangerous symptoms have manifested themselves during the inhalation, and have required such treatment as the application of the tongue forceps, or artificial respiration.

Transient **nausea, retching, and vomiting** are not as frequent after chloroform as after ether; but troublesome and distressing vomiting is probably more common after chloroform. Owing to the smaller quantities of mucus secreted under chloroform, coughing and straining are not so frequently witnessed as immediately after the withdrawal of ether. This has led many to think unfavourably of ether in this respect. But we ought hardly to reckon the transient ether-retching as in any way inconvenient: it very soon passes off. When vomiting

comes on after chloroform, it is more likely to prove distressing to the patient, and intractable to treatment.[1] Ether-vomiting is like ether-hæmorrhage—brisk at the time, but unlikely to recur. Chloroform nausea and retching often persist after the stomach has ejected its contents[2] (supposing food, mucus, etc., to have been present[3]).

Bronchial and pulmonary affections are exceedingly rare after chloroform, although they are not unknown; and in those exceptional cases in which they have been reported it is highly probable that other causes than the anæsthetic itself have been wholly or partly responsible. For example, a prolonged operation upon an elderly, bronchitic subject may be followed by such complications, more especially if extensive cutaneous surfaces have been exposed; but it would be wrong under such circumstances as these to throw the whole of the blame upon the anæsthetic. Speaking generally, we may disregard the possibility of any respiratory sequelæ.

Transitory **mental and muscular excitement**, similar to that referred to when dealing with the after-effects of ether, may occur in hysterical and neurotic subjects. **Delirium** lasting three days has been recorded.[4] **Loss of speech**[5] (attributed to cerebral hæmorrhage) has also supervened after chloroformisation. Persons who have had **maniacal attacks** before the administration of chloroform have been known to suffer from a recurrence of their mental disorder after the use of this anæsthetic.[6]

According to Sokoloff[7] and Ajello,[8] temporary **albuminuria** is very common after the administration of chloroform, and in

[1] Snow refers to a case in which vomiting after chloroform proved fatal; and others have occurred.

[2] This is pointed out by Mr. Marcus Gunn (*Brit. Med. Journ.*, 19th Sept. 1885).

[3] Snow and Clover reckoned that vomiting took place in 1 out of 7 cases. They probably refer to severe cases only—not to transient vomiting. Mr. Rigden (see footnote, p. 305) found vomiting to occur in 32·86 per cent of his cases, and of these it was noted as troublesome in 16·17 per cent.

[4] See a case (*Ether as an Anæsthetic*, by Josiah de Zouche, M.D., of Otago), in which delirium lasting three days, in a boy of fourteen, was met with after chloroform-inhalation.

[5] *Lancet*, vol. i., 1870, p. 553. Chloroform was given for a tooth-extraction. The aphasia lasted five weeks.

[6] See Savage, *Brit. Med. Journ.*, 3rd Dec. 1887, p. 1199.

[7] *Wratsch*, St. Petersburg, No. 4, 1891.

[8] *Annals of Surgery*, March 1897.

patients with pre-existing albuminuria some increase in albumen may be produced. Further evidence on this point is, however needed. Thiem and Fischer[1] state that the urine may show traces of chloroform—the drug existing in an unchanged state—even twelve days after the administration.

In very exceptional cases **jaundice** has been induced by the use of chloroform.[2]

Lastly, it has been alleged that the prolonged or frequent inhalation of chloroform may be followed by **degenerative changes in the heart, liver, and other organs.** Ungar, Strassmann, Thiem, Fischer, and Ostertag[3] have investigated this point. The last-named observer's results have been referred to in a preceding section (p. 95). Guthrie[4] believes that chloroform may produce fatal after-effects in children by causing extensive fatty degeneration of liver tissue and symptoms similar to those met with in acute yellow atrophy.

F. ILLUSTRATIVE CASES

The following cases will illustrate many of the points to which reference has been made in the preceding portions of this chapter.

It may be well, in the first place, to quote a couple of normal cases.

Illustrative Case, No. 11.—F., æt. 19. Tall: well developed: has a flabby appearance, especially about lower part of face: full lips: no thoracic abnormality discoverable. Removal of caseous cervical glands. Administration lasted one hour. Skinner's inhaler. Breath held a little at first. No excitement or struggling. Respiration became gradually deeper and rougher. After 5-6 min. colour good, respiration regular and rough, pulse good and rather slow, pupils 3 mm., conjunctiva barely sensitive. Operation commenced. No reflex movement. Respiration continuing satisfactory, a slight lid-reflex was permitted, but if this reflex became at all marked more chloroform was given. Less chloroform allowed the breathing to become quieter, the pupils smaller, and the lid-reflex more marked. More chloroform had exactly

[1] *Deutsche medizinale Zeitung.* Berlin, 2nd Dec. 1889.

[2] Murchison, *Diseases of the Liver*, 2nd edition, p. 407.

[3] See "On Some Fatal After-Effects of Chloroform on Children," by Leonard G. Guthrie, M.D. (*Lancet*, 27th Jan. 1894, p. 193; and 3rd Feb. p. 257).

[4] *Op. cit.*

opposite effects. After stitches had been put in, and the anæsthetic withdrawn, the pupils enlarged, and the conjunctiva became very sensitive. In a second or two retching commenced, and a little mucus was ejected. Pupils then gradually got smaller.

Illustrative Case, No. 12.—Florid, intelligent girl, æt. 16 : average height, and slim build : pupils 4½ mm. Removal of glands from neck. Administration lasted 46 min. Skinner's inhaler.

2.5 P.M. Administration commenced.

2.9 „ Muttering and swallowing.

2.11 „ Pupils 4 mm.

2.12 „ Ready for operation. Pupils 3-3½ mm. Snoring regular breathing. No movement with incision, but pupils went to 4 mm.

2.14 „ Less stertor. More chloroform. Stertor more marked and pupils 5 mm. No lid-reflex. Very good colour and pulse.

2.16 „ Pupils as before. Less chloroform seemed to make pupils, if anything, larger.

2.19 „ Pupils still 5 mm.: doubtfully active to light. Florid colour.

2.20 „ An act of deglutition. Pupils 4 mm. with lid-reflex. Increased quantity of chloroform now produces larger pupil.

2.23 „ A slight cough. Pupils 4½ mm. Increased the chloroform. Cough subdued. Slight crowing with inspiration. Chloroform again increased to subdue it. Pupils 5 mm. No lid-reflex. Pulse good and regular, about 75.

2.28 „ Whilst glands being removed from neighbourhood of carotid and jugular the respiration became shallow, and pulse a trifle less full. This shallow respiration lasted 2-3 mins. Lips briskly rubbed with good results. Pupils 4½ mm. No lid-reflex.

2.32 „ Respiration stertorous and deeper again. Good pulse : doubtful lid-reflex.

2.35 „ Pupils 3½ mm. No lid-reflex. A little moaning with expiration, and less stertor. Chloroform increased, and with result of deeper stertor and larger pupil. (Obvious influence of more chloroform in causing a larger pupil.)

2.36 „ Slight cough and crowing breathing. Anæsthetic increased.

2.38 „ Pulse very good.

2.41 „ Pupils 4 mm. Doubtful lid-reflex. Administration continued. Pupils 4½ mm.

2.42 „ Quieter respiration. Slight expiratory moan suggestive of impending cough, and pupils became 3½ mm. Stitches now put in, and pupils at once dilated to 5 mm.

2.51 „ Administration discontinued.

In the following case, which I take from Dr. Sheppard's notes, aortic and mitral disease were present.

Illustrative Case, No. 13.—F., æt. 35. Aortic and mitral disease. Ovariotomy. Worked almost entirely by the pupil, and phonation occurring during expiration. The following was the sequence :—

(a) { Contracted pupil,
Conjunctival reflex present,
Expiratory phonation :

Then (b) { Pupil gradually dilated,
Conjunctival reflex abolished,
Slight expiratory phonation :

Then (c) { Dilated and fixed pupil, and
Cessation of phonation.

About m.xv. of chloroform took the patient through all these stages: and the recovery back to contracted pupil took, roughly, a minute or so. Laryngeal musical stertor present all through, and not much affected by position of head or pulling jaw forwards. Pulse good all through, and patient came well and quickly out of the narcosis.

The administration of chloroform to a patient suffering from dyspnœa due to an enlarged thyroid is exemplified in the following case. As the dyspnœa did not increase under the anæsthetic, but actually diminished, it was probably the outcome of laryngeal spasm rather than of pressure upon the trachea.

Illustrative Case, No. 14.—M., æt. 17. Tall: slim: full lips rather nervous. Occasional distress in breathing. Prefers to be propped up somewhat. Dry sounds throughout both lungs. Occasional moist cough. Audible stridor on taking a deep breath. Large thyroid growth. Operation 10 A.M.: dry, bright, cold morning. Chloroform on lint. Administration, 1 hour 13 minutes; operation, 1 hour 5 minutes. Two oz. of chloroform used. Head and shoulders slightly raised. Anæsthetic cautiously given. Barely audible breathing became audible (both inspiration and expiration). Thought it best, as breathing seemed to be getting rather laboured, not to push anæsthetic. Long incision. Very slight reflex movement, and deeper breathing. Occasional swallowing. Rather free hæmorrhage. Breathing grew quieter, *although no part of growth yet removed.* Thyroid now removed. Pulse got slightly feeble during extraction of left lobe, which was deeply seated; it then improved. Conjunctival reflex often present, with large (5 mm.) pupil: more chloroform abolished reflex and made pupil smaller (3 or 2½ mm.). Pupils hence good guide. Face rather pale. No movement throughout. During removal of left lobe, transient inspiratory stridor of high pitch, but no cyanosis. No flattening of trachea discovered.

The following case seems to indicate that the presence or absence of the lid-reflex may be dependent upon the nature of the operation in progress (see p. 57).

Illustrative Case, No. 15.—F., æt. about 50. Febrile. Of spare build. Heart-sounds and chest expansion good. Exploration and evacuation of a tubercular kidney. Skinner's mask. Administration lasted 1 hour 20 minutes. An abdominal incision was first made, and subsequently a lumbar opening. After about one hour the patient's condition was as follows, the operator working at the lumbar opening:—Pupils contracted: lid-reflex either completely absent or only present in the slightest degree: pulse good, regular, about 72: respiration quiet. The operator now passed in sponges through the abdominal wound, with the *immediate* result that the breathing became deep, the colour more florid, and so much lid-reflex appeared that the lids tightly contracted when the conjunctiva was touched. We might say that this patient was, at the moment referred to, sufficiently anæsthetised for the lumbar operation, but not for the abdominal. The interest of the case, however, lies in the reappearance of the lid-reflex as the direct result of a particular stimulus, namely, intereference with the peritoneum.

CHAPTER XII

BROMIDE OF ETHYL, ETHIDENE DICHLORIDE, AMYLENE (PENTAL), AND OTHER ANÆSTHETICS

A. BROMIDE OF ETHYL

Administration and Effects produced.—The anæsthetic properties of bromide of ethyl were first recognised by Nunneley of Leeds in 1849, who spoke highly of the drug. Rabuteau[1] and Turnbull[2] were the next to investigate its anæsthetic properties. The latter has used it in a considerable number of cases, and has on more than one occasion brought its anæsthetic merits before the notice of American surgeons, several of whom, including Dr. Chisholm,[3] Dr. Levis, Dr. Marion Sims, and others, have employed it with more or less success. The late Sir B. W. Richardson[4] considered the bromide a good and efficient anæsthetic. Clover, however, who gave the agent a trial, was not favourably impressed with it.[5] Dr. H. C. Wood of Philadelphia is also opposed to its introduction into general use. Drs. Schneider and Herz,[6] as well as other German dentists, have used bromide of ethyl in their practices, and speak highly in its favour for dental operations. Dr. J. F. Silk[7] has also investigated the properties of the bromide as an anæsthetic in this branch of surgery. He administered it in

[1] *Lancet*, vol. i., 1877, p. 143.
[2] *Manual of Anæsthetics.*
[3] Dr. Chisholm has used bromide of ethyl in 3000 cases without a fatality. See *Maryland Med. Journ.*, 5th December 1880.
[4] *Asclepiad*, 1885, p. 264.
[5] *Brit. Med. Journ.* vol. i., 1880, p. 586.
[6] *Internationale klinische Rundschau*, 14th April 1889. See also *Lancet*, 27th April 1889, p. 848.
[7] *Trans. Odont. Soc. of Great Britain*, February 1891.

over 130 cases, and took notes of the effects produced. I have therefore largely availed myself of the information and conclusions contained in Dr. Silk's paper on the subject.

All who have employed bromide of ethyl in surgical practice agree that it is more adapted for operations of very short duration than for others. It often produces an analgesic rather than an anæsthetic effect, and has hence been somewhat extensively used in dental practice. It rapidly destroys consciousness; and recovery from its influence is correspondingly speedy.

The administration may be conducted by means of a towel or leather mask (Fig. 26, p. 270), but an Ormsby's inhaler (Fig. 36, p. 282) is very suitable for the purpose. A drachm, or a drachm and a half, should be placed upon the sponge of this inhaler, and the apparatus applied to the face of the patient. Dr. Silk recommends that little or no air should be admitted for the first few inhalations, after which the air-cap of the apparatus may be opened. With regard to the time occupied in producing anæsthesia, Dr. Silk found this to be, on the average, 66 seconds; whilst the duration of anæsthesia was 46 seconds. When the inhalation exceeded two minutes, the after-effects were liable to be troublesome. Of 300 cases in which Dr. Chisholm administered bromide of ethyl the time required to produce deep anæsthesia was not more than 60 seconds.

As to the signs of anæsthesia, the administration should be conducted till softly snoring breathing, or insensibility of the cornea, is produced. Should there be delay in the supervention of these signs, the inhaler must be removed on the detection of any feebleness or irregularity in the pulse. A single and continuous administration in this manner is not likely to be attended by any unpleasant after-effects; but a reapplication of the inhaler will be liable to induce nausea and vomiting. An intermittent administration, such as that which would be necessary for a prolonged operation, is therefore not to be recommended. Dr. Marion Sims[1] performed Batty's operation, using bromide of ethyl as the anæsthetic, and the administra-

[1] See a paper read before the New York Academy of Medicine, March 1880, entitled "The Bromide of Ethyl as an Anæsthetic." By J. Marion Sims, M.D.

tion lasted 1½ hour. Vomiting occurred several times; the conjunctiva was sensitive from the beginning to the end: opisthotonos, very rapid breathing, and violent straining were produced. Severe pain in the head followed the inhalation, and after attacks of diarrhœa, tenesmus, and convulsions, the patient died (21 hours after the operation). Dr. Levis of Philadelphia administered the bromide for 40 consecutive minutes with an expenditure of 11 drachms. Other observers also record prolonged administrations.[1]

When bromide of ethyl is administered as above recommended, respiration is not markedly affected. It remains for the most part regular, and free from those temporary embarrassments which are common with nitrous oxide or ether.

Professor Wood of Philadelphia regards bromide of ethyl as a cardiac depressant. During its administration the pulse usually becomes increased in rate, and somewhat diminished in force. In several of the patients to whom Dr. Silk administered the bromide, he found that distinct irregularity and slowing of the pulse were to be detected.

Struggling and excitement are exceptional. Dr. Turnbull records hysterical excitement in 6 out of 100 cases. This absence of early excitement is doubtless a great point in favour of the bromide. The pupils usually dilate during the administration, and profuse salivation and sweating are not uncommon.

Dangers connected with the Administration.—Several deaths have occurred during or immediately after the administration of this anæsthetic; but as it is difficult or impossible to ascertain the number of times bromide of ethyl has been employed, the actual death-rate is unknown. There is good reason to believe that the risks attendant upon the administration have been over-estimated, and that if a pure drug be employed, and ordinary care exercised, the rapid induction of anæsthesia sufficient for the performance of a short operation is attended by little or no danger. Dr. Silk, who has investigated all the published fatal cases, says that in some of these (1) sudden and early heart-failure occurred; in others (2) respiratory paralysis took place somewhat later in the administration; and

[1] See Norton, *Brit. Med. Journ.*, 15th May 1880, p. 735.

in others again (3) gastro-intestinal symptoms were recorded. Gleich[1] reports a case in which the face became cyanotic and pulse and respiration ceased together. The post-mortem showed no hyperæmia of the brain, but there was fatty degeneration of all the viscera. A fatal administration is also reported in the *Dental Cosmos*, August 1880. Jendritza[2] refers to a case in which unconsciousness, trismus, and dilated pupils came on after recovery from this anæsthetic administered for tooth-extraction, the condition lasting 90 minutes.

After-Effects.—As with other agents, the after-effects bear a kind of proportion to the duration of the anæsthesia. A short administration is usually not followed by headache or nausea, the patient regaining consciousness very satisfactorily. It is not very uncommon, however, for some degree of depression to be experienced, and in some cases actual fainting has been recorded. Hysterical outbursts may sometimes follow the inhalation. Nausea and vomiting are exceptional after a single administration; but during or after a comparatively long inhalation they will be liable to result.

Looked at from all points of view, bromide of ethyl can hardly be regarded with much favour. As compared with nitrous oxide it is distinctly inferior not only in point of safety, but in the greater liability after its administration to headache, nausea, and other unpleasant effects. Before any very definite opinion, however, can be expressed as to its suitability for use in dental and other minor surgical operations, a more extensive trial of the drug should be made. Its greater portability is necessarily a recommendation when we compare it with nitrous oxide; but its liability to decomposition quite outweighs this advantage.

B. ETHIDENE DICHLORIDE

Administration and Effects produced.—Ethidene dichloride was first employed as an anæsthetic by Snow,[3] who

[1] *Deutsche medizinale Zeitung*, Berlin, August 1892.
[2] *Year-Book of Treatment*, 1897, p. 172.
[3] Most of the information contained in the present chapter is derived either from the reports of the Glasgow Committee on Anæsthetics (*Brit. Med. Journ.*,

administered it on several occasions with good results. Snow found the effects to be nearly the same as those of chloroform. In 1870 it was used by Leibreich and Langenbeck in Berlin,[1] and by Sauer[2] and Steffen.[3] In 1879 the Glasgow Committee of the British Medical Association[4] drew attention to the merits of the anæsthetic, and, after a careful comparison of its action with that of chloroform, published their results in the following year. Fifty operations were performed under ethidene dichloride, fifty under chloroform, and the results tabulated. They found the average dose of ethidene to be 40·3 c.c., or 1·8 c.c. for each minute during which the patient was under its influence. With chloroform the average dose was 31·8 c.c., or 1·7 c.c. per minute. The time taken to produce anæsthesia was, in the case of ethidene dichloride, 4·3 minutes; whilst with chloroform it was 5·4 minutes. Less excitement was observed than with chloroform. The Committee found that both the pulse and the respiration under ethidene dichloride were less altered than when chloroform was used. They did not obtain the marked slowing of the pulse and the quick respiration which are often observed with chloroform. Ethidene dichloride was regarded by the Committee as midway, in point of safety and in other respects, between chloroform and ether; and after their eulogistic account of its action it was for a time largely used. Mr. Tom Bird[5] has recorded six administrations by means of Junker's apparatus. Mr. J. H. Palmer[6] has also reported his experiences with the agent administered upon lint or by means of a towel. He found that one ounce was required to anæsthetise a boy of eighteen for an operation lasting 35 minutes. We are indebted, however, to Clover[7] for the records of no less than 1877 administrations of ethidene dichloride, and his results are of great interest. Of the 1877 administrations, 287

18th December 1880, p. 958); from a lecture given by the late Mr. Clover (*Brit. Med. Journ.*, 29th May 1880, p. 797); or from Dr. Snow's article on "Monochlorurretted Chloride of Ethyle" (*op. cit.* p. 420).

[1] *Berlin klin. Wochenschrift*, Nos. 31 and 33, 1870, p. 401.

[2] *Pharm. Centralblatt*, vol. xiv. p. 140.

[3] *Deutsche Klinik*, No. 44, p. 398; and *Jahresb. der Medicin*, 1870-1-2.

[4] *Brit. Med. Journ.* vol. i., 1879, p. 108.

[5] *Med. Times and Gaz.* vol. i., 1879, p. 62.

[6] *Lancet*, vol. ii., 1879, p. 637. Mr. Palmer obtained his ethidene from Kahlbaum of Berlin, through some London chemists.

[7] *Brit. Med. Journ.*, 29th May 1880, p. 797.

were for major operations. Clover usually preceded the administration of ethidene by nitrous oxide gas, using his combined gas-and-ether inhaler (p. 403) for the purpose. The vapour of ethidene was gradually added when the patient was partly anæsthetised by nitrous oxide. By this method struggling was rarely met with. A little convulsive twitching occurred as anæsthesia approached, and this was quickly followed by stertor and dilatation of the pupils. Air was then admitted as occasion required; and the quantity of ethidene given was regulated by the general condition of the patient. Clover seems, in fact, to have administered ethidene in very much the same way as he employed ether, *i.e.* with a limited supply of air.

Dangers connected with the Administration.—Sauer, to whom reference has already been made, has recorded a fatality under ethidene in a patient who was the subject of morbus cordis. Another fatality is reported by Clover[1]; but from the published account of the case the anæsthetic seems to have had but little share in bringing about the fatal syncope which followed the administration. The patient had a large flabby heart, and syncope took place whilst the head was being voluntarily raised after the operation was over. A third case is put on record by Dr. Mouillot.[2] The patient was the subject of empyema, and died with symptoms of syncope soon after the stage of struggling. A fourth fatality is mentioned[3] as having occurred during an ophthalmic operation. Pallor and disappearance of the pulse were noticed at the moment the cornea was incised. It may be incidentally mentioned that ethidene seemed at one time to be specially suited for ophthalmic operations, owing to the infrequency of struggling during its administration, and of vomiting afterwards. There can be no doubt, however, that ethidene, although more stimulating than chloroform, is yet to be regarded in this respect as inferior to ether. Clover refers to three cases in which alarming symptoms presented themselves during the administration, and in his remarks on the fatality above alluded to, states his belief that ether would have been safer than ethidene.

[1] *Loc. cit.* [2] *Brit. Med. Journ.* vol. i., 1881, p. 385.
[3] *Ibid.* vol. ii., 1882, p. 1267.

After-Effects.—According to Clover, patients recover from ethidene anæsthesia very satisfactorily. He found vomiting to occur in one-third of his administrations for major operations, and in one-twentieth of those for minor operations. He further states that vomiting after ethidene invariably ceases sooner than after chloroform. Of thirty-three cases mentioned by Sauer, two vomited, and two had nausea and headache after. The Glasgow Committee found that nausea and vomiting were about equal in frequency after ethidene and after chloroform, but that vomiting after ethidene was of shorter duration than that after chloroform.

C. AMYLENE. PENTAL.

Amylene

Administration and Effects produced.—For most of our present knowledge concerning the effects produced by amylene we are indebted to Snow, who, as already mentioned, was the first to employ this substance as an anæsthetic. Snow used it in 238 cases, and found that the best results were obtained by administering it with his chloroform inhaler (p. 314). The great volatility of amylene almost necessitates the use of some special apparatus. Snow found that three to four fluid drachms were required to cause insensibility in the adult, and that about 15 per cent of the vapour should be breathed with air. Amylene appears to differ from chloroform in that the continuous administration of a very dilute vapour does not lead to anæsthesia; it is necessary to exhibit the agent in a somewhat concentrated form. Owing to the sparing solubility of amylene in the blood, and to its great volatility, patients very rapidly emerge from its influence, so that a frequent renewal of the inhalation is necessary. Snow estimated that amylene was consumed at about the rate of one fluid drachm per minute, when administered by means of his apparatus.[1]

In most of Snow's administrations an analgesic and not a truly anæsthetic state appears to have been obtained. He declared, indeed, that he found it possible to secure an absence

[1] *Med. Times and Gaz.*, 17th January 1857, p. 60.

of pain with a less profound coma than that which characterised the use of chloroform or ether. The lid-reflex was not as a rule abolished, although muscular movements in reflex response to operative interference were usually absent. Both major and minor operations were performed during this comparatively light form of anæsthesia. The pulse was almost always increased in frequency and force. The respiration was often accelerated. The pupils were most commonly about the ordinary size. The colour of the features was heightened. Perspiration was met with in some cases. It was found that amylene could not be depended upon for producing complete muscular relaxation, and that it was not a very convenient anæsthetic for prolonged operations about the mouth or face. It appeared to answer best in short operations not requiring muscular flaccidity, such as those for the extraction of teeth. Less salivation was observed than under ether or chloroform.

Soon after the introduction of amylene by Snow, it was tried somewhat extensively both in this country and abroad. The conclusions arrived at by a Committee of the Academy of Medicine were[1]: That rigidity was the rule rather than the exception during amylene administration; that a remarkably rapid recovery from its effects occurred; and that it was more suitable for brief operations than for others. Its unpleasant odour was regarded as a barrier to its general employment. M. Giraldès administered amylene to 79 children, and stated that two drachms were required in most cases to produce insensibility to pain. According to Kappeler,[2] amylene was given a fair trial by Spiegelberg and Lohmayer, who were unable to obtain complete anæsthesia with it; whilst Billroth and Jüngken found it answered well as an anæsthetic, even in major operations (resection of os calcis, amputation of leg, etc.).

Dangers connected with the Administration.—In Snow's 238 cases there were two fatalities; but in discussing these by the light of our present knowledge it is questionable whether they should be directly attributed to the influence of

[1] See *Med. Times and Gaz.* vol. i., 1857, p. 623.

[2] *Op. cit.* p. 192.

the anæsthetic. In one case the pulse failed at the moment the incision was made for *fistula in ano*, the patient being only lightly under the anæsthetic. In the other the patient was in the prone position,[1] and, from the fact that breathing had been observed to be noisy and snoring, it is quite possible that other factors than the toxic action of the amylene may have been at work. These, however, are merely conjectures. The patients appear to have died from cardiac failure in much the same way that has frequently been observed in the case of chloroform. The occurrence of these two fatal cases had the effect of lessening the confidence of the profession in the new anæsthetic; and it does not appear to have been again employed, at all events as amylene. The body recently introduced as pental will be discussed below.

After-Effects.—Patients recover with remarkable rapidity from the effects of amylene. Nausea and vomiting are quite exceptional. Of Snow's 238 cases there were only two in which vomiting occurred immediately after the administration; and sickness was only heard of subsequently in eight or ten cases.

Pental

The substance known by this name has been already referred to (p. 35). What the precise differences between it and its predecessor amylene may be, further experience must decide. Pental has been somewhat extensively used in Germany as an anæsthetic in dental surgery, and the following remarks, for most of which I am indebted to Mr. T. E. Constant[2] of Scarborough, apply to its employment in that branch of practice.

Administration and Effects produced.—A Clover's ether inhaler (p. 273), or some similar apparatus, answers best. Two drachms, or a little more, should be poured into the reservoir. The bag being attached, the patient's expirations may be allowed to partly fill the bag. The indicator must be turned to "1" when the apparatus is applied to the face. No more air is given, but the patient breathes to and fro for

[1] See p. 139.

[2] The pental used by Mr. Constant was procured from C. A. F. Kahlbaum of Berlin.

about 40 seconds, the indicator being progressively pushed towards "F." The symptoms produced are similar to those recorded by Snow. The face flushes, the pulse becomes quicker and quicker, the pupils dilate, the eyes are fixed and open, the conjunctival reflex disappears, the breathing is quick and laboured, and there is slight cyanosis. There may be some opisthotonos. It is sometimes possible to obtain true analgesia, the patient retaining consciousness whilst a tooth is painlessly extracted. At the end of about 40 seconds, the inhaler is removed and the extraction commenced. Anæsthesia is stated to persist for about a minute after the removal of the face-piece.

Dangers connected with the Administration.—Several fatalities in connection with the use of pental have been recorded.[1] A case has also been reported to me in which the most alarming symptoms occurred immediately after the inhalation. Respiration grew shallow and then ceased, whilst the radial pulse became imperceptible. Inversion restored the pulse; but artificial respiration for 7 minutes had to be resorted to before recovery ensued. Looked at from all points of view, the use of amylene or pental seems to have but little to recommend it. As compared to nitrous oxide for brief operations it is certainly inferior, not only because of its greater danger, but because it is not so agreeable to inhale.[2]

After-Effects.—As with the amylene employed by Snow, after-effects are usually completely absent.

D. OTHER ANÆSTHETICS

There are numerous other agents which have been used for the production of general anæsthesia; but they are all inferior, in one way or another, to those already discussed.

Nitrogen is capable of producing insensibility to pain when inhaled free from oxygen, or with very small percentages of that gas. The anæsthesia must be regarded as the result of oxygen-deprivation, for it is obvious that we cannot

[1] See *Brit. Journ. Dent. Science*, 1st and 15th June 1892; *Lancet*, 4th Jan. 1896, p. 45; *Dental Record*, Nov. 1893, vol. xiii. p. 511.

[2] For further remarks see *Wiener klin. Woch.*, 21st and 28th Jan. 1892.

assign any specific anæsthetic properties to nitrogen itself. In 1868,[1] Professor Burdon Sanderson, the late Dr. John Murray and Mr. J. Smith Turner administered nitrogen for tooth-extraction to six patients at the Middlesex Hospital. In the first two cases a considerable quantity of air appears to have been breathed with the nitrogen; and even in the remaining four cases there is good reason to believe, from the results obtained, that in some way or another unknown quantities of oxygen must have gained access to the lungs during the administration. Thus, insensibility did not occur till from 3 to 4 minutes after the commencement of the inhalation: no lividity of the features was observed; and in only two of the four cases was there an absence of pain during the operation.

On 13th May 1890, I administered, at the Dental Hospital, for Sir George Johnson, nitrogen with ·5 per cent of oxygen (*i.e.* practically pure nitrogen) to nine patients. There was no excitement in any case. An onlooker could not have detected any difference between the phenomena produced and those usually met with under nitrous oxide. I used the same apparatus which I employ for nitrous oxide (Fig. 16, p. 212) and took great care that the face-piece fitted well and that the valves worked accurately, so that no air whatever might gain admission to the lungs. Anæsthesia was produced with remarkable rapidity in each case. The available period of anæsthesia for a dental operation was, with one or two exceptions, shorter than with nitrous oxide. There was reflex screaming in some of the cases; but this is also met with under nitrous oxide, more especially in hospital practice. I administered the nitrogen in each case till slight epileptiform movements appeared. The recovery was quick and good. There was no nausea or vomiting. The pulse was usually rapid, and I am inclined to think not so strong as under nitrous oxide.

On 26th May 1890, I administered nitrogen with 5 per cent of oxygen to five cases; and nitrogen with 3 per cent of oxygen to four cases. A longer time was taken to produce anæsthesia than with the practically pure nitrogen; but the period of inhalation was still remarkably short. The resulting anæsthesia seemed to be longer than that obtained by nitrogen

[1] See *Brit. Med. Journ.*, 13th June 1868, p. 593.

alone. No excitement was noted in any case. During the administration there was less jactitation in these than in the preceding nine cases. In one case three teeth were painlessly extracted. There was some excitement after the inhalation in a few of the cases. One patient, a boy, complained of much headache, and cried with pain. In one case there was rapid tremor of one arm after the administration. This phenomenon I also observed in one of the pure nitrogen cases. All patients exhibited jerky and irregular breathing, with cyanosis.

On 29th May 1890, I administered nitrogen with 5 per cent of oxygen to one case. The anæsthesia was not satisfactory. On the same day I administered to two cases nitrogen with about 6·6 per cent of oxygen. There was a longer period of inhalation than with the 5 per cent of oxygen, and some apparent discomfort and uneasiness. In one of these cases I pushed the administration till slight clonic movements, irregular respiration, and cyanosis occurred. The anæsthesia was then complete for a short operation.

On 3rd June 1890, I administered nitrogen with 7 or 7½ per cent of oxygen to two patients. In both there was distinct anæsthesia. In one case, a woman, there was no jactitation, but some cyanosis, and the patient was quiet throughout. In the second, a woman, the symptoms were like those of pure nitrogen or nitrous oxide, coming on more quickly. There was definite anæsthesia.

Sir George Johnson, in his report of the above administrations of nitrogen with ·5 per cent of oxygen, states that "the maximum period required to produce anæsthesia was 70 secs., the minimum 50 secs., and the mean time 58·3 secs." With regard to the cases in which 3 per cent of oxygen was present, Sir George Johnson states that "the time required to produce anæsthesia varied from 60 to 75 secs., the average time being 67·5 secs." Referring to the cases in which 5 per cent was present, he states that "the time required for the production of anæsthesia ranged from 75 to 95 secs., the average being 87·5 secs."[1]

[1] For further information see *Lancet*, 11th April 1891, p. 815. Sir George Johnson gives the details of some administrations of nitrogen conducted for him by Mr. Woodhouse Braine.

Although anæsthesia undoubtedly follows the inhalation of nitrogen, the results are not so satisfactory as when employing nitrous oxide. As in the case of the latter gas, a continuous inhalation is necessarily impossible, so that only very brief operations can be performed under its influence.

Ethyl chloride, C_2H_5Cl, a colourless mobile liquid with a pleasant odour, and boiling at 12·5° C. (Regnault),[1] is described by Richardson[2] as a good anæsthetic. It is extremely soluble in alcohol. When thus dissolved, the solution may be kept in well-stoppered bottles, and the ethyl chloride obtained by gently heating. According to Kappeler,[3] the anæsthetic properties of ethyl chloride were recognised by Flourens and others, and it was used successfully in several cases by Heyfelder. Quite recently[4] it has been employed upon the Continent for minor surgical operations, and the results are stated to have been satisfactory; whilst in this country Dr. W. J. McCardie has given it a trial. The best apparatus for the administration appears to be that of Breuer, consisting of a tightly-fitting face-piece with inspiratory and expiratory valves, and furnished with a small spherical metallic receptacle for holding a piece of lint or absorbent cotton-wool, upon which the ethyl chloride is poured. This receptacle is in communication with the inspiratory valve through which the vaporised ethyl chloride enters the face-piece. Lotheissen of Innsbruck recommends that from 3 to 5 gm. of the anæsthetic should be placed in the metal receptacle before the face-piece is applied. The initial sensations are similar to those of nitrous oxide (McCardie). There is little or no excitement; anæsthesia (or in some cases analgesia) is rapidly induced; and recovery quickly takes place. Owing to the fact that the muscular system does not as a rule become relaxed, ethyl chloride is not so suitable as other anæsthetics for prolonged operations. Lotheissen found that from

1 Roscoe and Schorlemmer, vol. iii. part i. p. 344.

2 *Med. Times and Gaz.*, 28th Dec. 1867, p. 693.

3 *Op. cit.* p. 185.

4 The reader is referred to a paper by Dr. Nogué (*Archives de Stomatologie et Journal de l'Anesthésie*, Sept. 1900), in which will be found a *résumé* of the results obtained by certain Continental surgeons with chloride of ethyl. See also *Archiv für klinische Chirurgie*, 1898. The article by Dr. G. Lotheissen has been translated by Dr. W. J. McCardie (*Birmingham Med. Review*, Jan. 1900). See also *Lancet*, 9th March 1901, p. 698.

8 to 10 gm. were needed for short cases. Unpleasant after-effects are said to be exceptional, but McCardie has met with vomiting in several cases. Further experience with this agent is necessary before any definite statements can be made as to the precise place it should occupy in the list of general anæsthetics.

Methyl oxide, or **di-methyl ether,** $(CH_3)_2O$, a gas of an agreeable odour, and capable of being condensed to a mobile liquid boiling at $-21°$ C. (Berthelot), has been used as an anæsthetic by Richardson,[1] who speaks in its favour. In twenty-seven instances sufficient insensibility was induced to permit of the painless extraction of teeth; and in all cases recovery took place within a minute. Analgesia rather than true anæsthesia appears, however, to have been produced.

Ethylene, or **olefiant gas,** was administered by Nunneley of Leeds in 1849 to four patients; but it was found to be unsatisfactory in its action.

Amyl hydride,[2] **amyl chloride,**[3] **ethyl nitrate,**[4] **benzene,**[5] and **turpentine**[6] have one and all been found to be capable of producing general anæsthesia when administered in the form of vapour.

[1] *Asclepiad*, 1887, p. 135; *Med. Times and Gaz.* vol. i., 1868, p. 581.

[2] *Lancet*, vol. i., 1885, p. 101; *Asclepiad*, 1885, p. 168; *Med. Times and Gaz.*, 28th Dec. 1867, p. 694.

[3] Kappeler, *op. cit.* p. 190.

[4] Snow, *Med. Times and Gaz.*, 17th Jan. 1857, p. 61.

[5] Snow and Richardson, *Med. Times and Gaz.*, 17th Jan. 1857, p. 61; and 28th Dec. 1867, p. 694.

[6] *Med. Times and Gaz.*, 28th Dec. 1867, p. 694; and Kappeler, p. 193.

CHAPTER XIII

ANÆSTHETIC MIXTURES

MIXTURES consisting of chloroform and alcohol, chloroform and ether, and of chloroform, alcohol, and ether, have been very extensively employed not only in this country but upon the Continent. The object in adding alcohol and ether to chloroform has been, not only to prevent too concentrated a chloroform vapour from being respired, but to counteract any tendency to circulatory depression. By mixing a small quantity of alcohol with chloroform it is obviously possible to administer a chloroform vapour considerably weaker than that which would result were the undiluted agent administered in precisely the same manner; whilst mixtures of ether and chloroform have been shown, by comparative experiments, to produce a better cardiac action than chloroform alone.[1] There is, however, an objection to these mixtures, and one which Snow particularly laid stress upon. It is that as the constituents have their own special rates of evaporation, the more volatile ingredients will be first vaporised, the less volatile remaining behind to be subsequently respired.

Ether and chloroform, for example, have very different boiling-points, whilst the rates of diffusion of their respective vapours will follow the same law as that which obtains in the case of gases—that is to say, they will be inversely as the square roots of the densities of those vapours (see Chap. II.). It is therefore clear that in using a mixture of equal parts by volume of liquid ether and chloroform, not only will the proportions of the anæsthetics in the mixed vapour be widely

[1] *Trans. Roy. Med. Chir. Soc.* vol. xxix., 1864, p. 342.

different from those in which the liquids were mixed, but there will be considerable fluctuations in these proportions throughout the administration. Ellis[1] overcame this objection by devising an apparatus which contained the anæsthetics separately, and their vapours were mixed in the desired proportions during the administration. The plan was very ingenious, but too complicated for general use. There is another way, however, in which the objection above referred to may, to a great extent, be overcome, at all events in the case of certain mixtures, viz. by employing such proportions of the liquid constituents as will evaporate in the same period of time at the same temperature. When it is impossible to adjust the proportions in this manner, the anæsthetist must administer small quantities of the mixture at a time, and frequently replenish the mask or inhaler, thus endeavouring, as far as possible, to get rid of one dose before another is added. Although Snow was not favourably disposed towards anæsthetic mixtures, Clover appears to have used certain of them with success. The latter[2] took advantage of the stimulant effect of ether by mixing 4-8 minims with every 30 minims of chloroform, and found that he obtained a better pulse than with the last-named anæsthetic alone. When fatty degeneration of the heart was supposed to exist he advised and employed a mixture of chloroform and ether, containing one-sixth of the latter agent. He also used the A.C.E. mixture, and believed it to be specially appropriate when moderate narcosis was required for a long time. Various administrators since the time of Snow and Clover have also eulogised anæsthetic mixtures, especially for certain cases. But although these mixtures possess their advantages, they require special care in their use. They must not be looked upon as definite bodies capable of producing definite and characteristic phenomena, but rather as mixtures capable of producing mixed symptoms, dependent upon the physiological actions of the constituent anæsthetics, and upon the proportions in which those anæsthetics are present.

1 *Medical Times and Gazette*, vol. i., 1867, p. 246.
2 *British Medical Journal*, 14th February 1874.

A. MIXTURES OF CHLOROFORM AND ETHYLIC ALCOHOL

Sansom[1] recommended and used **equal parts of chloroform and alcohol,** and believed that the good effects he obtained were due to the alcohol restraining the volatility of the chloroform, and thus preventing too concentrated a vapour. Others, including Snow, have employed this mixture with success.[2] When alcohol is used with chloroform it is, however, generally added in smaller proportions, *i.e.* to the extent of one-fourth or one-fifth. If one-fifth of alcohol be added, and the mixture be administered by means of a Junker's inhaler, it will be found difficult to anæsthetise vigorous or alcoholic subjects, although more susceptible patients will be readily affected.

Mixtures of alcohol and chloroform should be **administered** in precisely the same manner as the undiluted anæsthetic.

B. MIXTURES OF CHLOROFORM AND ETHER

A mixture consisting of **one part of chloroform and two parts of ether** was examined and used by the Committee of the Royal Medical and Chirurgical Society, who found it to be very similar in its action to the A.C.E. mixture referred to below. Ellis,[3] in his inquiries into anæsthetic mixtures, considered it very unreliable, as it parted with its ether rapidly, and with its chloroform very slowly; and this has been my experience. A death under its influence has been reported.[4] Dr. Edgar B. Truman[5] has investigated this mixture from a chemico-physical point of view, and his results are very interesting. He concludes that during the initial stages of its administration 100 volumes of ether vapour to ·95 volumes of chloroform would be inhaled; whilst at the last, 100 volumes of ether to 75 of chloroform would be breathed.

A mixture containing **one part of chloroform and three parts of ether,** often known as **the Vienna mixture,** has been exten-

[1] *Medical Times and Gazette*, vol. ii., 1870, p. 107.
[2] See Stephens, *British Medical Journal*, January 1888, p. 19.
[3] *Medical Times and Gazette*, vol. i., 1867, p. 246.
[4] *Ibid.* No. 849, p. 378.
[5] *Lancet*, 16th Feb. 1895.

sively used abroad, a large number of administrations having been recorded without a casualty. Observers in this country have, however, stated that it is uncertain and irregular in its action.[1]

A mixture consisting of **one part of chloroform and four parts of ether** was examined by the Committee above mentioned, and was reported to be very similar in its action to ether itself.

For some time past I have extensively used a mixture of **two parts of chloroform and three of ether,** that is to say, the "A.C.E." mixture without its alcohol. For purposes of brevity and description this will be termed the **C.E. mixture.** Although the presence of alcohol is generally supposed to be essential in order that ether and chloroform may remain perfectly mixed, I have been unable to satisfy myself of this supposed advantage. In actual practice, indeed, I find that I obtain better results with the C.E. than with the A.C.E. mixture. There is less excitement during the administration and a more satisfactory recovery afterwards, differences which are probably dependent upon the absence of the alcohol. Personally I have never seen with either mixture any practical difficulties dependent upon the different rates of vaporisation, and I am strongly of opinion that if very small quantities of these mixtures be added from time to time to an appropriate inhaler no such difficulties need be feared. If, as is unfortunately often the case, an ounce or so of a chloroform-ether mixture be placed in a closed inhaler, the anæsthetist is courting accident, and dangerous or fatal symptoms may readily arise. Such symptoms, however, are not dependent upon the fact that irregular percentages of the two anæsthetics are breathed, but upon ignorance of the principles upon which chloroform should be used.

Mixtures of chloroform and ether should be administered by means of "open" or "semi-open" inhalers, such as those represented in Figs. 47 and 26. Bag-inhalers should not be employed. The greater the proportion of chloroform, the nearer should the mode of administration approach to that described on p. 327; and, above all, frequent additions of small doses are essential. Some anæsthetists[2] employ Junker's

[1] *Lancet*, vol. ii., 1872, p. 828.
[2] See Tyrrell, *Clinical Journ.*, 26th Jan. 1898.

system of administration (p. 315), using one bottle for ether and one for chloroform, and varying the proportions of the two vapours from time to time.

C. MIXTURES OF ALCOHOL, CHLOROFORM, AND ETHER

1. **The A.C.E. Mixture.**—This mixture consists of one part of alcohol, two of chloroform, and three of ether. It was originally suggested and used by Dr. George Harley. Some years later the Committee of the Royal Medical and Chirurgical Society made a careful trial of it, and with very favourable results. They recommended it as preferable to chloroform; and this recommendation is to a great extent accountable for the present extensive employment of the mixture. According to the Committee the specific gravities of the constituents should be—

Alcohol	·838
Chloroform	1·497
Ether	·735

Martindale states[1] that by employing—

Alcohol	sp. gr.	·795	1 part,
Chloroform	,,	1·497	2 parts,
Ether	,,	·720	3 parts,

he obtains a mixture which volatilises uniformly.

Properties.—When freshly prepared from the purest ingredients (all kinds of methylated ether should be avoided), and when inhaled gradually and with plenty of air, the A.C.E. mixture possesses an agreeable, somewhat fruity odour, and is certainly as pleasant as, or even more pleasant than chloroform itself. The mixture is more stable than is usually supposed, and it is quite possible that some chemical change, of which we are at present in ignorance, takes place when the alcohol, chloroform, and ether are mixed. The A.C.E. mixture should be freshly prepared, and kept in small, tightly-stoppered bottles.

Administration.—Two cardinal points should be borne in mind—(1) To give a plentiful supply of air with the vapour;

[1] *Extra Pharmacopœia.*

and (2) to employ small quantities (say half a drachm) at short intervals, in preference to placing a larger quantity (say 2 or 3 drachms) upon the inhaler at one time. I have found a drop-bottle of the shape shown in Fig. 51, p. 327, but of larger size, to answer well. The inhaler used should be simple in construction. A Skinner's mask may with advantage be employed to commence the inhalation, as closer forms of inhalers may cause discomfort to the patient. Children and weakly persons may be kept satisfactorily anæsthetised without any further apparatus; but in other subjects a Rendle's inhaler, a felt cone open at the apex, or a cone-shaped cloth similarly arranged for a free air-supply may be needed. The air-holes in Rendle's inhaler (p. 270) should be large, in order to provide for a very free supply of air. If a Skinner's mask be used throughout, a considerable time may be taken in anæsthetising an average adult patient. If, however, the mask be kept more or less completely saturated, anæsthesia will eventually result. Clover's and Ormsby's inhalers should not be used; nor is Junker's apparatus suitable, owing to the inconvenience of frequently replenishing it with small quantities of the mixture.

Effects.—When the A.C.E. mixture is administered with the precautions already described, it produces effects which are, in their main features, similar to those met with when employing chloroform.[1] There are, however, as we should expect, certain obvious differences in the two cases. As the administration proceeds, respiration gradually becomes deeper and more audible, as with chloroform itself; but unless care be taken to avoid too strong a vapour, swallowing, holding the breath, and coughing will be more easily excited than with undiluted chloroform. There is somewhat more mucus and saliva produced than with the last-named anæsthetic; but not nearly so much as with ether. Any attempt at retching or vomiting must be met by carefully continuing the administration. The administrator should not attempt to get his patient ready for operation in too short a space of time: from 5 to 8 minutes are usually necessary. Old persons, very fat subjects,

[1] The Hyderabad Commission state (*Lancet*, vol. i., 1890, p. 158) that this mixture gives the same tracings as chloroform alone.

middle-aged emphysematous and bronchitic patients will often be found to take the A.C.E. mixture remarkably well, and to pass into quiet anæsthesia with little or no trouble. Stertorous, regular breathing, absence of lid-reflex, muscular flaccidity, a fixed state of the globes, and a moderately contracted pupil are the signs which should be looked for and maintained when quiet and profound anæsthesia is desired. As with chloroform and ether, the respiration should be kept softly snoring if possible. The breathing is, in fact, one of the best guides; any tendency to quiet respiration being probably due to too light a narcosis. When any doubt exists as to the degree of anæsthesia present, other signs must be consulted. The lid-reflex and pupil are both good guides. The latter during deep anæsthesia is generally either the size of that already described as almost characteristic of chloroform anæsthesia, or is a trifle larger; but, as with all anæsthetics, variations not unfrequently occur. I have notes of several cases, for example, in which it was necessary to maintain a pupil of $3\frac{1}{2}$ or 4 mm., any attempt to work with a pupil of $2\frac{1}{2}$ or 3 mm. being at once followed by signs of imperfect anæsthesia, such as rigidity, tendency to cough, etc. Should a dilated pupil be associated with distinct lid-reflex, more of the mixture may be given if desired; but should such a pupil exist with an insensitive cornea, the anæsthetic must be withheld until the pupil has become smaller, or the lid-reflex re-established. More should then be given in small quantities. Respiration during the use of the A.C.E. mixture is usually deeper than in the case of chloroform; but not so deep or so liable to temporary embarrassment as with ether. The colour of the features, too, is liable to be somewhat more dusky than with chloroform itself, probably because of the greater secretion of mucus and saliva. High-pitched crowing breathing must be carefully treated. As a general rule the anæsthetic should be withdrawn for a while and the lips briskly rubbed (p. 447), but if the condition be obviously associated with imperfect anæsthesia, as will be ascertained by other signs, the administration may be cautiously continued, being at once stopped if the crowing does not subside. The circulatory phenomena of a patient under the A.C.E. mixture are very similar in many

respects to those observable in the case of chloroform. The pulse is, however, generally fuller and quicker than the chloroform pulse, and probably less liable to become affected by those depressing influences which may come into play in chloroform narcosis proper. In infants and very young children, the proper degree of anæsthesia may be arrived at by observing the breathing, the condition of the general muscular system, and the pupil. Very quiet breathing, a tendency to rigidity of the arms or legs, expiratory phonation, swallowing movements, and a very small pupil point to a light anæsthesia. A few drops of the mixture will generally suffice to produce deeper breathing, relaxation of the muscles, and a moderately contracted or medium pupil.

The A.C.E. mixture is by many regarded as the best anæsthetic for routine use. For example, the late Mr. Moss, of King's College Hospital, writing to me in 1889, informed me that he had then employed it in over 10,000 cases, and with excellent results.[1] The cases in which, according to my own experience, the A.C.E. mixture is specially serviceable are considered in Chaps. VI. and VII.; whilst the special advantages which the mixture seems to possess as a preliminary anæsthetic before ether will be discussed in the following chapter.

As already mentioned (p. 389), the C.E. mixture produces similar, and if anything even more satisfactory results than the A.C.E. mixture; and the foregoing remarks are equally applicable to its use.

The following illustrative cases may be of interest as showing the value of the A.C.E. or C.E. mixture:—

Illustrative Case, No. 16.—(This case occurred in the practice of my friend Mr. Marmaduke Sheild, to whom I am indebted for the following notes.) "Patient an engine-fitter, aged 42. A brawny, heavily-built man. Neck practically obliterated by an enormous swelling, reaching from the malar bones to the sternum, livid in colour, and hard and board-like to palpation. Much dyspnœa. Face livid and bedewed with sweat. Pulse weak and quick. Unable to speak or open mouth. Nitrous oxide had been given and an exploratory incision commenced; but the man had so nearly died that the operation was abandoned. It was obvious he was suffering from pressure upon the larynx and trachea. I ordered him

[1] See an interesting letter on the value of this mixture in *Brit. Med. Journ.* vol. ii., 1880, p. 797.

to be given the A.C.E. mixture in a large cone with a plentiful supply of air. I further requested that the administration should be very gradual. It was quite ten minutes before slight rigidity and struggling took place. The patient seemed unconscious to pain, but was not completely flaccid. I made a free incision on the right side of the neck. The tissues did not bleed. The deep fascia was carefully incised, and I then passed my finger behind the carotid sheath into a large abscess cavity, from which a quantity of pus gushed out. The inspiration instantly became more free, but as there was still some difficulty I made a free incision in the middle line of the neck. Instantly the patient began to respire deeply and easily. The anæsthetic had been discontinued at the commencement of the operation, and consciousness was returning. The man was able to speak, though with a hoarse intonation, and he expressed his gratitude at his relief. The subsequent progress of the case was perfectly satisfactory."

Had this patient been placed very deeply under the anæsthetic, or had the close method of inhalation been adopted, respiration would in all probability have come to a standstill.[1]

The A.C.E. mixture is often of great use in patients in whom grave respiratory difficulties from other causes than tracheal narrowing are present. The following case, in which the breathing was embarrassed by the most extreme abdominal distension that I have ever witnessed, may be quoted :—

Illustrative Case, No. 17.—F., æt. 37. Thin anxious face : slightly dusky complexion : very breathless and orthopnœic : hands cold : pulse quick and feeble : chest walls thin : abdomen enormously distended with ascitic fluid and large ovarian tumour : heart much pushed upwards. As the patient was sitting upright upon an operating-table I had to administer the anæsthetic standing upon a chair. Judged it best to work with two different stages of anæsthesia : (1) Light anæsthesia during removal of ascitic fluid ; and (2) deep anæsthesia during removal of tumour. Stage (1) conducted with A.C.E. mixture : ether tried, but not well borne. Several gallons of fluid evacuated gradually : patient analgesic rather than anæsthetic. One by one pillows removed as fluid evacuated. Breathing gradually improved. During stage (2) patient recumbent, and chloroform given on Skinner's mask. Pulse got rather weak, but improved with hot-water flushing. Subsequently weaker again. Patient removed to bed.

In cases of peritonitis, intestinal obstruction, etc., with a fixed and inactive abdomen, and some respiratory difficulty,

[1] An almost precisely similar case to the above is reported in the *Brit. Med. Journ.*, 29th Oct. 1892. Ether was used and the patient succumbed under its influence. See also another death, *Lancet*, 23rd March 1895 (chloroform).

he A.C.E. mixture is perhaps the best anæsthetic. The following is an example:—

Illustrative Case, No. 18.—F., æt. about 19. Ill for one week with peritonitis. Abdomen distended. Slightly under morphine. Rather lethargic. Pulse fair and full, but compressible and quick. Colour good. Occasionally vomits blackish fluid. Abdominal section. Operation lasted half an hour. A.C.E. given on Skinner's mask. Took it well. After some minutes I changed to ether (Clover's inhaler), but this was not well borne, so went back to A.C.E. Kept her lightly under. Nearly all the time she was as follows:—Pupils 2 mm.: some conjunctival reflex, which was allowed to disappear for a few seconds at a time: respiration fairly regular, not stertorous, but deeper and quicker than before administration: colour good: pulse quicker and quicker, getting from about 90 to 120: right hand and arm moved occasionally. She vomited once on operating-table. Whilst intestine and ovary were being manipulated respiration grew quicker, and a kind of "catch" in breathing was noted. No crowing respiration. After removal of anæsthetic colour not so good, though fair: hands warm: pulse quick: conjunctiva soon sensitive. Patient remained lethargic for some time.

As already indicated (p. 129), the A.C.E. mixture is a valuable anæsthetic in most cases of advanced cardiac disease. It seems particularly useful when mitral stenosis is present. The three following cases occurred at the London Hospital, and I am indebted to Mr. W. Penberthy for the notes:—

Illustrative Case, No. 19.—F., æt. 36. Mitral stenosis. Retro-uterine abscess. Operation lasted 20 minutes. A.C.E. on Skinner's mask. Went under readily, and easily kept under. Mask frequently removed for a breath or two. *The patient had formerly taken ether with a nearly fatal result.*[1]

Illustrative Case, No. 20.—F., æt. 24. Mitral stenosis. Perineorrhaphy. Operation half an hour. A.C.E. given as in previous case, with equally favourable result.

Illustrative Case, No. 21.—F., æt. 25. Mitral and aortic regurgitation. Operation on cervix uteri: 40 minutes. 13 dr. of A.C.E. mixture used on Skinner's mask. Result very good.

The A.C.E. mixture is also about the best anæsthetic I know for patients with advanced emphysema and bronchitis attended by fatty degeneration and dilatation of the heart. I quote the following case, as it was a particularly anxious one, so far as the anæsthetic was concerned. The question, in

[1] An interesting case in which ether almost proved fatal in mitral stenosis is reported by Mr. Arthur Jefferson (*Lancet*, 20th Sept. 1884, p. 492). Chloroform was subsequently given with good result.

fact, had arisen as to whether it was advisable to give any anæsthetic at all. I selected the A.C.E. mixture, and fortunately it answered well.

Illustrative Case, No. 22.—M., æt. about 70: average build: look 80. Half propped up in bed. Breathing rather hurried: expiration distinct and audible. Respiratory movements almost wholly diaphragmatic. Chest front hyper-resonant: wheezy sounds over it. Heart sounds "flapping": an occasional murmur in apical region: much epigastric pulsation. Pulse very irregular and intermittent. Face congested: bluish red colour. He is subject to seizures of difficult breathing and cyanosis. Has a large prostate, and catheter has to be used every two hours. Operation supra-pubic cystotomy. Administration lasted 35 minutes. A.C.E. mixture. Gradually given on Skinner's mask. Respiration deeper and expiration more wheezy. No distress. Pulse improved, and became more regular and fuller; but never got quite regular. Face remained flushed. Some perspiration. Muttering. Conjunctiva still sensitive. Eyes commenced turning upwards. Then slight rigidity. No struggling. Catheter passed. Little if any reflex effect. Abdominal muscles tense, and respiration jerky. Distension of rectum by bag caused slight but not inconvenient movement. Skin incision also caused slight reflex movement, but absolutely no effect on wrist-pulse. During most of administration his condition was as follows:—Conjunctiva just sensitive, once or twice insensitive: respiration wheezy, with noiseless inspiration and difficult expiration: pulse as before: pupils about 4½ mm. The hands gradually got chilly, and perspiration increased. No nausea or vomiting after.

After-Effects.—The after-effects of the A.C.E. mixture are, as a rule, slight, although nausea and vomiting are not uncommon in very protracted administrations. It is, in my experience, quite the exception for a short inhalation (10-15 minutes) to be followed by anything but the most trifling discomfort. Old persons are rarely affected by after-sickness, even though the administration has lasted for a long time.

Dangers.—The signs of an overdose are closely allied to those observed under chloroform. Several fatalities have occurred under the A.C.E. mixture. This is not to be wondered at when we reflect that the mixture is very extensively employed for anæsthetising patients whose general condition is extremely unfavourable. The mixture is often chosen for those who are considered unfit for chloroform on the one hand, and for ether on the other. Then, again, the erroneous practice exists of regarding this mixture as a stable

and definite body, and of administering it in large doses seldom repeated, instead of in small doses often repeated. Furthermore, in some of the fatal cases[1] a bag-inhaler has been employed.

2. **Other Mixtures.**—Mixtures of alcohol, chloroform, and ether, containing these agents in somewhat different proportions from those of the A.C.E. mixture, have also been employed. **Billroth's mixture**, consisting of one part of alcohol, three of chloroform, and one of ether, is in great favour with many Continental surgeons. It is administered very much as chloroform is employed, and is said to be rarely followed by vomiting.

D. THE SO-CALLED "BICHLORIDE OF METHYLENE" OR "METHYLENE."

Composition.—The so-called "bichloride of methylene" or "methylene" was brought before the notice of the profession in 1867 by Sir B. W. Richardson,[2] who gave it the formula CH_2Cl_2, and strongly recommended it for producing surgical anæsthesia. The "methylene" supplied by Messrs. Robbins and Co. distils over at about 127°-128° F.,[3] and the temperature is stated not to vary more than 3° from first to last during distillation. As supplied by the manufacturers, "methylene" is a colourless fluid, with an agreeable odour very similar to that of chloroform. Much discussion has taken place as to the precise chemical nature of "methylene." Whilst on the one hand Sir B. Richardson maintained that the drug sold under that name was, with the exception that it contained traces of alcohol and water, chemically pure CH_2Cl_2, very strong evidence has been adduced to show that "bichloride of methylene" is nothing more than a mechanical mixture of chloroform and methylic alcohol.

The "methylene" employed in a fatal case at Prague was carefully analysed by Professor Hofmeister,[4] who found it to be a mixture of chloroform diluted with one-fifth of methylic alcohol. This "methy-

[1] *Brit. Med. Journ.*, 24th Oct. 1891, p. 906.
[2] See *Asclepiad*, 1888, p. 201—"Methylene as an Anæsthetic."
[3] See *Brit. Med. Journ.* vol. ii., 1883, p. 271.
[4] *Brit. Med. Journ.*, 21st July 1883.

lene," which had come from the recognised London manufacturers, h… sp. gr. of 1·3495 at 17·1° C. (68·78° F.), commenced distilling at 47 … (116·60° F.), and continued between 49° C. and 53° C. (120·2° F. … 127·4° F.). One-fifth of the "methylene" mixed readily with wa… and gave the tests for alcohol. After separating the alcohol, the resi… boiled at 59·5°-60·5° C., and the distillate had a density of 1·4885 a… 17·1° C., and gave the usual tests for chloroform. As already sta… (p. 99), MM. Regnauld and Villejean[1] prepared some true bichloride … methylene, and compared it with the anæsthetic fluid supplied … English makers under that name. They found that bichloride … methylene had a sp. gr. of 1·334, and a boiling-point of 40·4° C. (104… F.), and that it was unsuitable for producing surgical anæsthesia. Finally they agreed with Professor Hofmeister that the English "bichloride … methylene" consisted of chloroform and methylic alcohol. Dr. Junker, indeed, administered a mixture of chloroform and methylic alcohol[2] … in several cases. The mixture had a sp. gr. of 1·237, and produ… effects which appeared to him to be precisely similar to those obse… with the so-called "bichloride of methylene."

Effects.—But whatever may be the chemical constituti… of Richardson's "methylene," it certainly produces effe… which deserve careful consideration from a clinical point … view. The first operation under its influence was perform… by the late Sir Spencer Wells, who, after a very lar… experience,[3] still considered "methylene" to be superior to a… other agents. For several years after its introduction int… practice, it was used somewhat extensively not only in thi… country but on the Continent. Its rapidity of action,[4] th… speedy return to consciousness after its use, and the strikin… rarity of after-effects rendered it specially serviceable in abdominal, ophthalmic, and dental operations. Dr. Day,[5] wh…

[1] *Comptes Rendus de la Société de Biologie*, tom. i., 1884, p. 158. See a… *Bull. Acad. Med.* 2nd Sér. tom. xii. p. 568.

[2] *Brit. Med. Journ.* vol. i., 1884, p. 451.

[3] See *Lancet*, vol. ii., 1890, p. 898 ; and vol. ii. 1877, p. 191.

[4] I cannot agree with those who state that "methylene" is a rapidly-acti… anæsthetic. It may quickly destroy consciousness when given in a somewha… concentrated vapour. But when administered by means of Junker's apparatu… 10, 15, or even 20 minutes may be required to induce anæsthesia. Indeed, not long ago, I met with a case in which I had to resort to another agent, a… I was unable to secure tranquil and perfect anæsthesia with "methylene." The drug I used was freshly prepared. The patient was a tall, vascular, an… powerfully-built woman of 60. After pumping with Junker's inhaler for abo… 20 minutes the patient was only partially anæsthetised. I then had recour… to the A.C.E. mixture, and in three minutes she was ready for operation.

[5] "Methylene as an Anæsthetic" (*Brit. Med. Journ.*, 14th July 18… p. 72).

dministered "methylene" for Sir Spencer Wells and other urgeons in 1230 cases, most of which were cases of abdominal ection, spoke in very high terms of the agent. He found hat it was less likely than chloroform to cause vomiting; that t was more agreeable to inhale; that rarely more than 3 to 4 drachms were required for an operation lasting half an iour; that consciousness returned in a few seconds after the nhalation had been discontinued; that it might be used when erious heart and lung affections existed; and that, so far as iis experience went, "methylene" was the best anæsthetic. Others have spoken in similarly favourable terms.[1] There are, nowever, two sides to every question, and many surgeons iave tried "methylene" and have discarded it. It enjoyed, for example, a long reign at the Samaritan Hospital, but was eventually replaced by its former rival chloroform. Nussbaum of Munich, who in 1868, had administered "methylene" 15,000[2] times without an accident, found its effects very similar to those of chloroform, but, according to Kappeler,[3] he met with considerable excitement, rigidity, and nausea in many cases. Hégar and Kaltenbach, who have largely used "methylene" with Junker's inhaler, do not consider it safer than chloroform, but find less vomiting after its use. Kappeler endorses these views.

Administration.—With regard to the administration of "methylene," Junker's apparatus (p. 315) has been found to be the best for the purpose. Rendle's[4] mask (p. 270) is used by some, but with this apparatus the danger of an overdose, and of asphyxial troubles, is certainly greater than with Junker's inhaler. As the liquid is more volatile than chloroform, an open mask such as Skinner's is not so applicable. The administration should be conducted as has been already described when considering chloroform (p. 319). Difficulty may be experienced in obtaining true surgical anæsthesia in many cases, especially when using Junker's inhaler. It must, therefore, be borne in mind that in operations upon very

[1] *Lancet*, vol. i., 1882, p. 371.
[2] *Med. Times and Gaz.* vol. i., 1868, p. 111.
[3] *Anæsthetica*, p. 105.
[4] *Brit. Med. Journ.* vol. ii., 1880, p. 729.

sensitive parts, and when dealing with patients who are not easily affected by anæsthetics, it may be necessary either to give more of the anæsthetic than can be administered by Junker's inhaler—that is to say, to use some other inhaler—or to change to ether, chloroform, or the A.C.E. mixture.[1] The anæsthesia produced by "methylene" is, in fact, comparatively superficial, and would hardly satisfy most surgeons of the present day.

Dangers.—Several deaths have occurred during the use of "methylene"[2]; the symptoms being almost identical with those which characterise chloroform fatalities. Inversion has been successfully tried in a case of threatened death.[3]

E. OTHER MIXTURES

Amongst the numerous other mixtures which have been employed, those introduced by Schleich[4] in 1898 deserve notice. This observer states that by mixing chloroform, ether, and petroleum ether[5] an anæsthetic liquid may be produced which boils between 38° C. and 42° C., according to the proportions of the ingredients, and that, by slightly adjusting these proportions in accordance with the body temperature of the patient, absorption and elimination may be so balanced that no accumulation of the anæsthetic within the circulation is possible. Theoretically, each inspiration of an anæsthetic boiling at the blood temperature would be eliminated by a corresponding expiration. Anæsthetics with high boiling-points, such as chloroform, are rapidly absorbed and slowly eliminated, owing to the temperature of the blood being below such boiling or maximum evaporation points. The more volatile the anæsthetic, the less will be absorbed by the blood

[1] Two cases (rectal operations) are reported by Mr. Martin Coats, in which he found it necessary to replace "methylene" by chloroform (see footnote, p. 398).

[2] See *Lancet*, 23rd Oct. 1869: *Brit. Med. Journ.*, 7th May 1870; 29th April 1871; 16th Sept. 1871; 31st Aug. 1872; 12th Oct. 1872; 19th Oct. 1873: *Lancet*, 2nd Dec. 1874, p. 881: and *Brit. Med. Journ.*, 24th July 1875.

[3] *Lancet*, vol. ii., 1876, p. 462.

[4] See *Therap. Gazette*, 1898, p. 98.

[5] It is stated that the petroleum ether should have a boiling-point between 60° and 65° C.

in a given time, and the more rapid will be its elimination. Schleich's "No. 1" mixture consists of—

Chloroform	45	parts
Petroleum Ether . . .	15	„
Ether	180	„

and boils at 38° C. "No. 2" consists of—

Chloroform	45	parts
Petroleum Ether . . .	15	„
Ether	150	„

and boils at 40° C. "No. 3" consists of—

Chloroform	30	parts
Petroleum Ether . . .	15	„
Ether	80	„

and boils at 42° C. So far as I am aware, these mixtures have not been employed in this country. One observer[1] has published his experiences in 700 cases, and these are by no means encouraging. The weak point in Schleich's argument is the assumption that his mixtures are definite anæsthetic liquids capable of yielding definite vapours. This assumption, however, is not warranted, and although we are not perhaps justified in criticising his system of anæsthetising without having tested it, there is no reason to believe that Schleich's mixtures possess any tangible advantages over those already discussed.

[1] See Dr. Rodman's interesting paper, *New York Med. Rec.*, 1st Oct. 1898.

CHAPTER XIV

ANÆSTHETIC SEQUENCES

In certain subjects, in certain operations, and under certain special conditions, it is advisable (*a*) to induce anæsthesia with one anæsthetic and to maintain it with another; or (*b*) to employ two anæsthetics successively for the induction period and a third for the subsequent stages of the administration; or (*c*) to use certain of the mixtures which have been described, either one after the other or in conjunction with some simple anæsthetic such as ether or chloroform. Thus we have at our disposal a large number of anæsthetic sequences, and it will now be convenient to consider those which have proved themselves to be of the greatest clinical value.

A. THE NITROUS OXIDE-ETHER ("GAS-AND-ETHER") SEQUENCE

We are indebted to Clover for the valuable suggestion and practice of administering nitrous oxide before ether. The former agent is a particularly appropriate one for *inducing* anæsthesia. It is by no means unpleasant to inhale; it rapidly destroys consciousness; its administration is not attended by excitement or struggling; and its use is practically free from risk to life. Although ether, as we have already seen, is the best anæsthetic for ordinary surgical work, the sensations which attend its administration are distinctly disagreeable. Nitrous oxide therefore supplies the very qualities in which ether is deficient. From the point of view of the patient it is a great boon not only to be quickly rendered unconscious, but to be spared the suffocative and other feelings which may attend the

initial stages of etherisation. Moreover, ether is a particularly appropriate anæsthetic to administer in conjunction with or immediately after nitrous oxide, because the exclusion of atmospheric air, which is essential in the case of the latter anæsthetic, is to a certain extent advantageous in the case of the former. In other words, we may pass from deep nitrous oxide to deep ether anæsthesia without admitting that quantity of air which would be essential were we dealing with chloroform.

Clover's first plan[1] for employing this sequence was to render the patient unconscious with nitrous oxide, and then to change the gas inhaler for an ether apparatus. His next method was to first administer nitrous oxide by itself, and then to gradually add ether by causing the gas to pass over this anæsthetic. After working at the subject for many years, he perfected his combined gas-and-ether apparatus, which is conspicuous for its ingenuity. Experience has proved, however, that this appliance is not only too cumbrous and complicated for general use, but that it possesses other disadvantages. The principal of these is that the channels through which the patient has to breathe are so constricted that considerable stress is thrown upon respiration; whilst it is difficult if not impossible to thoroughly cleanse all parts of the inhaler.

Clover's combined gas-and-ether apparatus consists of a gas cylinder and stand; an ether reservoir, which can be attached to the coat of the administrator by a hook; an inhaling-bag; a face-pipe with an expiratory valve in its side, for the escape of expirations when nitrous oxide is being breathed; and a regulating stopcock, which determines whether air, "gas," or "gas" mixed with ether shall be breathed by the patient. The regulating stopcock is connected on the one hand to the face-piece, and on the other to the bag and a flexible tube running through the bag.

To use the apparatus the ether reservoir is charged with 4 oz. of ether, and its tap turned off so that there may be no odour of ether. The bag is then emptied of any air which it may contain. The handle of the regulating stopcock is turned completely off the dial-plate, so that the air-slot is opened. The bag is then filled with nitrous oxide by working the foot-key of the gas cylinder. When the face-piece is applied, air is breathed backwards and forwards through the air-slot. The handle of the regulating stopcock is now placed at "G," and nitrous oxide is respired. Expirations escape at the expiratory valve in the side of the face-piece so

[1] *Brit. Med. Journ.*, 15th July 1876, p. 74.

long as the bag is kept more or less distended by fresh gas. After three or four breaths of "gas" the tap of the ether reservoir should be turned on. This will open up the way for the gas to pass over ether, but the gas will not *freely* circulate until the handle of the regulating stopcock is moved towards "E." This should be done a few seconds later. It is not as a rule necessary to use more than a bag or a bag and a half of "gas." When no more is needed the foot-key should be turned off and the supply tube subsequently disconnected from the apparatus. If too much "gas" be given, the so-called "stertor" of nitrous oxide narcosis may interfere with the free intake of ether. Should much clonic movement occur, a breath of air must be given, either by momentarily opening the air-slot again, or by removing the face-piece for half an inspiration or so of air. As the supply of nitrous oxide to the bag has now ceased, and as the bag has therefore lost all distension, to-and-fro breathing results, because the expiratory valve does not act. Nitrous oxide, ether, and air are thus breathed backwards and forwards. The handle of the regulating stopcock must be passed towards "E" till a sufficient degree of ether anæsthesia is reached. Stertorous breathing and insensibility of the conjunctiva usually supervene in about two minutes. The administrator should not admit too much fresh air, otherwise his patient will quickly come out of the anæsthesia. By degrees all nitrous oxide will escape from the bag, and the patient will therefore continue to breathe ether and air, without any nitrous oxide, backwards and forwards. After a while the handle of the regulating stopcock may be turned back somewhat, as less ether will be needed; and more air may thenceforward be allowed. Although this apparatus is intended for the use of nitrous oxide and ether in succession, it may be used for either of these anæsthetics alone.

Clover's original plan of first administering a full dose of nitrous oxide and then changing the gas apparatus for an ether inhaler has for many years been employed, with slight modifications, by Mr. Woodhouse Braine, whose method may be thus described:—

Any form of nitrous oxide apparatus capable of producing deep anæsthesia may be employed; and an Ormsby's ether inhaler with a large bag, as described on p. 281, will be needed. It is important that the sponge of the latter inhaler should be coarse, and that it should completely but loosely fill the cage. If plugged in tightly it will obstruct breathing and be more liable to freeze. The sponge must be wrung out in tepid water and placed in the inhaler, which should be within easy reach during the administration of nitrous oxide. The ether may either be added to the Ormsby's inhaler immediately before the inhalation of gas commences, or, should it be desired to prevent the patient detecting any odour of ether in the room, it may be poured upon the sponge after the gas face-piece has been applied. In the case of strong adults, about an ounce of ether should be added to the inhaler. For anæsthetising children and feeble subjects smaller quantities are advisable. Nitrous

oxide is administered in the ordinary manner (p. 213) until the usual signs of narcosis manifest themselves. At this point the gas face-piece is removed, and quickly replaced by the Ormsby's inhaler. It is usually said that no air should be admitted during the exchange of inhalers, and, roughly speaking, this is correct. But it is obvious that unless oxygen in some way or another gain access to the lungs, respiration cannot be expected to proceed. Moreover, at the very acme of nitrous oxide anæsthesia the pulse is often quick, small, or even indistinct at the wrist, more especially in feeble patients, and a breath or so of air is needed in order to re-establish the circulation.[1] I have used this method in a very large number of cases, and I find that the quantity of air which should be allowed during the transition is best regulated by the vigour and build of the patient. As a general rule, it is best to remove the gas face-piece during an expiration; to allow one inspiration of air; and to apply the Ormsby's inhaler during the following expiration. Some recommend[2] that the Ormsby's inhaler should be applied with the air-slot open, and that after a few moments the slot should be closed. Vigorous subjects require vigorous treatment, and in their case air should be sparingly given. In weakly subjects and in children a full breath, or even two breaths, of air may be allowed, and the ether may be more gradually applied. By placing the Ormsby's inhaler over the face during an expiration, its bag becomes partly distended with expired air, nitrous oxide, and ether. The following inspiration is invariably held for some little while owing to the strength of the ether vapour. Mr. Braine's rule, I believe, is to keep the ether inhaler applied till the patient breathes, unless the conjunctiva should, during the suspended respiration, become insensitive to touch, in which case the inhaler should be removed. If the patient has been placed thoroughly under nitrous oxide, he will not hold his breath so long as if only partial anæsthesia has been induced. A distinct, though brief period of suspended breathing and cyanosis must be looked for in this method, and need not of itself excite alarm. Florid, flabby subjects assume a very cyanotic appearance, but the administrator must not be in too great a hurry to admit air, otherwise quick recovery may ensue. The first inspiration through the ether sponge is usually a short and ineffectual one, but by degrees respiration grows deeper and more regular. At the approach of stertor a breath of air may be allowed again, and in this way good ether anæsthesia will quickly ensue. Difficulties are most common in patients of alcoholic habits, in those who are fat and flabby, in very muscular subjects with accurately-meeting teeth, and in individuals with partial or complete nasal obstruction. When

[1] If the pulse at the wrist be watched at this juncture, unnecessary alarm may be felt by the administrator. The contraction of the muscles of the arm probably helps to explain the almost imperceptible pulse which in some cases is observed. Dr. Russell Reynolds (*Epilepsy*, p. 271) states that the heart may be acting vigorously during an epileptic seizure, but the pulse may be nearly imperceptible at the wrist. A somewhat analogous state is probably induced when "gas" and ether are administered by this method.

[2] *Brit. Med. Journ.*, 24th January 1885, p. 209.

difficulties are, from the appearance of the patient, likely to arise, it is an excellent plan to place a little mouth-prop between the teeth (Fig. 56. p. 445) before giving "gas."

This plan of administering nitrous oxide and ether has, at first sight, much to recommend it. The apparatus required is simple; all chance of the odour of ether being detected by the patient may be obviated; and when once ether anæsthesia has become established there is no better inhaler than Ormsby's for maintaining it. The method, however, has one serious objection, viz. that during the change from nitrous oxide to ether, or to be more correct, during the first minute of etherisation, there is a liability, especially in certain subjects, to so much spasm about the upper respiratory passages as to introduce into the administration an element of great difficulty, if not of actual risk to life. I have given this method a very extensive trial during the past fifteen years, and, whilst admitting that there are many points in its favour, the objection to which I refer is to my mind too weighty to be disregarded. But whilst Mr. Braine's method has not in my hands proved as satisfactory as others for anæsthetising *men* and *women*, it is certainly valuable for children of from 3 to 13 or 14 years. In such subjects the respiratory spasm which comes about during the transition from one anæsthetic to the other is not so pronounced as in older patients. Although some suspension of breathing occurs when the strong ether vapour is applied—and this is particularly the case in children with adenoid growths and enlarged tonsils—respiration generally becomes quickly and spontaneously re-established. I now never use this method except for anæsthetising children.

Attempts have from time to time been made to administer nitrous oxide and ether by passing the gas through a Clover's portable ether inhaler. I do not propose to describe in detail what has been done in this direction, as no useful purpose would be served. The chief difficulty which has hitherto presented itself has been, that whereas for the successful administration of nitrous oxide the escape of expired "gas" is essential, at all events at the commencement of the inhalation no such escape of the expirations is necessary in administering ether—in fact, to-and-fro breathing is advisable. Some years

ago I devoted a considerable time to this particular matter. I found that by attaching a charged gas-bag to a Clover's inhaler, and by employing a stopcock which would allow of one-half of the nitrous oxide being breathed through valves, and of the remaining half being breathed backwards and forwards during the gradual admission of ether vapour, a very satisfactory result could be obtained.

In addition to a Clover's portable regulating ether inhaler (Fig. 28, p. 273), and a cylinder or pair of cylinders for the supply of nitrous oxide (Fig. 14, p. 209), all that is needed is a gas-bag capable of holding about, but not more than, two gallons of gas, and furnished with the special form of stopcock described in detail on p. 212. This is the same stopcock which I find to give the best results in ordinarily administering nitrous oxide. The ether chamber, which should be slightly warmed in cold weather, or when a very vigorous and muscular patient is about to be anæsthetised, should be charged with an ounce and a half of ether, and its indicator turned to "0." The gas-bag should be filled or nearly filled with "gas," according to the age and strength of the patient. Children will not need more than half a bagful. The bag may be disconnected from the gas supply tube and placed near at hand. A face-piece of appropriate size should be fitted to the ether chamber. It is a good plan for the administrator to apply the face-piece, with the ether chamber attached, to his own face, and to blow out through it, in order to expel any traces of ether vapour present. If this be done, and if care be taken not to unduly warm or shake the apparatus, there will be little if any odour of ether when the face-piece is applied to the patient's face.

The **administration is thus conducted.** If the patient be lying upon his back his head should be turned to one side. The face-piece with the charged ether chamber is then applied during an expiration. Air will be breathed backwards and forwards. When the respiration is seen to be proceeding freely, and the face-piece fits well, the charged gas-bag is attached to the ether chamber. Air will still be breathed, but now through the valves of the special stopcock. When the valves are heard to be working properly, "gas" is turned on, and is likewise breathed through the valves. Three or four respirations (or about one-half of the contents of the bag) are allowed to escape. The valve action is now stopped by turning the tap at the upper part of the stopcock. At the same moment at which the patient begins to breathe "gas" backwards and forwards, the rotation of the ether chamber, for the

addition of ether vapour, should be commenced. Rotation may be effected rather more quickly than when the ether chamber is used without "gas." The administrator will, in fact, find that he can, in a few seconds from the commencement of the administration, rotate the ether chamber as far as "1" or "1½" (Fig. 53). Should swallowing or coughing arise, he must rotate more slowly. Respiration soon becomes deep and regular, and more and more ether may be admitted. At about this juncture, if the apparatus has been fitting the face well, signs of nitrous oxide narcosis may appear, especially in those who are quickly

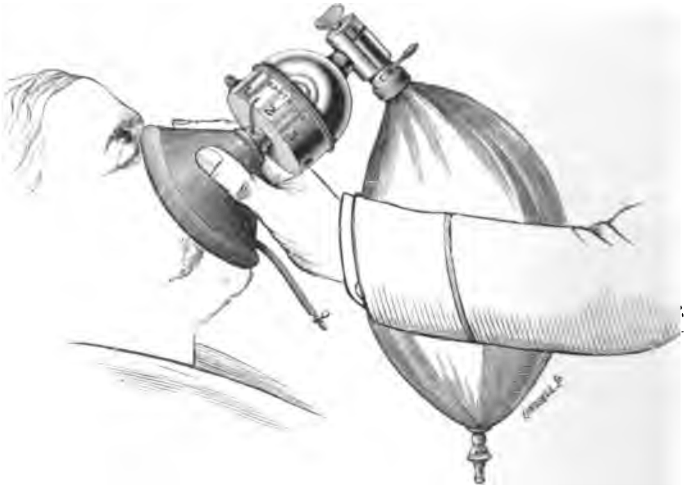


FIG. 53.—The Administration of Nitrous Oxide and Ether by means of a Clover's Portable Ether Inhaler, the author's Stopcock, and a detached Gas-bag.

affected by this gas. Should jerky breathing or "jactitation" arise, one full inspiration of air may be admitted at the air-tap. It should be remembered, however, that in giving "gas and ether" by this method, the object is to just steer clear of the clonus and "stertor" of nitrous oxide narcosis, and to gradually but increasingly mix ether with the gas. In muscular and vigorous subjects, the quantity of gas above mentioned will be found to be, as a general rule, insufficient to lead to the usual signs of deep nitrous oxide anæsthesia. The rotation of the ether chamber should be continued till the indicator points to "2," "3," or "F." The mistake that is most commonly made is

that of admitting air too soon. Should air be given during the first half or three-quarters of a minute, the patient will partially come round, hold his breath, set his teeth, and give a good deal of trouble. Duskiness of the features must be expected. Speaking generally, air should not be allowed till the patient is stertorous, when one breath may be given. In this manner the patient will continue breathing a mixture of nitrous oxide, ether, and air, till the usual signs of deep ether anæsthesia appear, when the gas-bag may be detached, and the little bag ordinarily used with Clover's inhaler substituted. This will necessarily admit more air, and the dusky colour of the features will hence become less pronounced. The administration may then be conducted as described on p. 280. It is a mistake to exchange the bags till the patient has been anæsthetised for about a couple of minutes.

For short dental or naso-pharyngeal operations, as well as for tonsillotomy, the surgeon often requires a rather longer anæsthesia than can be obtained by nitrous oxide, and there is no better method than this under such circumstances. Should the operator wish for an anæsthesia of one minute after the apparatus is withdrawn from the face, this period may usually be depended upon after an inhalation, as above directed, for two and a half or three minutes. After a little practice the administrator will be able to estimate with tolerable certainty the length of inhalation needed to secure the proper length of anæsthesia.

This plan of administering nitrous oxide and ether has numerous advantages. In the first place, it is precise—that is to say, given that the face-piece fits accurately, one has at one's command a definite and known quantity of each anæsthetic, and provided the method be carried out in the proper way, patients of similar type will evince similar phenomena. This is not so with many other methods. In the next place, only a limited quantity of nitrous oxide is needed, so that the bag may be filled before the patient enters the room, or it may be filled outside the room and carried in. The patient is thus spared the noise, etc., connected with the supply of gas to the gas-bag, and the administrator is spared the trouble of keeping up a supply of the gas with the foot-key during the adminis-

tration. The patient need never see the gas-bag. When the face-piece and ether chamber are applied, he may be told to close his eyes, and the gas-bag may then be adapted. One frequently has to give "gas and ether" to patients who are lying in bed, and under these circumstances it is a great convenience to have at hand a detached bag of gas containing

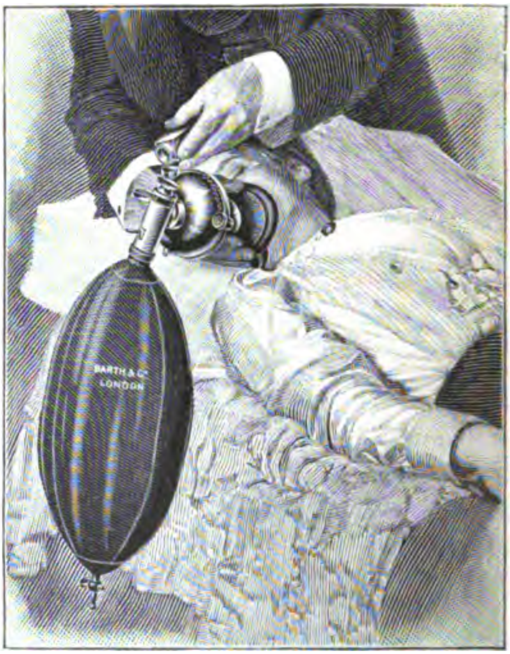


FIG. 54.—The Administration of Nitrous Oxide and Ether by means of the author's Stopcock and Modification of Clover's Inhaler.

sufficient, when used as directed, for any patient. Some have objected to the method on the ground that there is always a smell of ether in the apparatus when it is first applied to the face. But, by proceeding as above narrated, the odour will either be so slight that it matters but little, or will not be detected at all.

The modified Clover's inhaler described on p. 278 will be found to be particularly well adapted for this sequence of anæsthetics. It is so constructed that the ether can be intro-

duced *after* the inhalation of the nitrous oxide has begun. The face-piece must be adjusted upon the ether reservoir so that the open mouth of the wide filling-tube is horizontal and ready for the reception of ether at the proper moment. The face-piece, to which are attached the empty ether reservoir and full gas-bag, is now applied to the face, the indicating handle being at " 0 " and the filling-tube open. The patient first breathes air as described above; nitrous oxide is then turned on; and at the moment at which the valves of the stopcock are thrown out of action in order to allow of re-breathing, about $1\frac{1}{2}$ or 2 oz. of ether are rapidly introduced into the reservoir, and the plug of the filling-tube replaced. Ether vapour is now admitted by moving the indicating handle; air is allowed as required; and when full anæsthesia has become established the gas-bag is replaced by a smaller bag supplied with the apparatus. By this particular plan of procedure the patient is never conscious of the slightest odour of ether, and anæsthesia may be induced without excitement, struggling, or asphyxial complications. The advantage of having a large bore to the ether vessel has been already alluded to (p. 278), and this advantage is very conspicuous in passing from nitrous oxide to ether. I find, for example, that even when anæsthetising children with adenoid growths and enlarged tonsils, there are usually no asphyxial phenomena with this inhaler.

There is a simple way of administering nitrous oxide and ether employed by some anæsthetists. The metal angle-piece to which the bag of Clover's inhaler is attached is furnished with a small tap to which a tube from a gas cylinder may be fitted. The administration is begun by allowing some nitrous oxide to pass into the bag, and the patient breathes this backwards and forwards whilst ether is gradually mixed with it by rotating the ether reservoir. For reasons already given this plan is not so suitable as that just described, although it certainly has the merit of simplicity.

Considerable experience is necessary before nitrous oxide and ether can be smoothly and successfully administered in sequence. It is a mistake to suppose that this system of inducing ether anæsthesia is applicable to every patient whose general health is good. As already indicated (p. 112), the " gas-and-ether " sequence has its special sphere of applica-

bility. It must not be forgotten that there are certain special risks which belong to this particular system of anæsthetising and that by recklessness, inattention to detail, or improper selection of cases, difficulties and dangers may easily arise. Respiration must be carefully watched during the transition from one anæsthetic to the other.

B. THE CHLOROFORM-ETHER SEQUENCE

From some points of view chloroform is a particularly appropriate anæsthetic to administer before ether. It is not unpleasant to inhale; its exhibition requires no complicated apparatus; and a very small quantity is needed to render the patient unconscious. Chloroform has, indeed, been largely used to precede ether. But we must not lose sight of the fact that most of the fatalities during chloroformisation have either occurred at the very outset of inhalation or during the stage of excitement and tonic spasm, *i.e.* before true surgical anæsthesia has been produced. From this it follows that, in using chloroform for the purpose of preventing the initial discomforts of ether, we may be subjecting the patient to greater risk than in employing ether alone. The risk will be in proportion to the extent to which we carry the inhalation of chloroform. If we carry it only so far as to blunt the sensibility to the pungency of ether vapour, the additional risk will be practically *nil*. If we carry the administration as far as the stage in which excitement and tonic spasm are liable to arise, the risk will be increased. It is an established fact that during muscular excitement and respiratory embarrassment under chloroform, syncope may take place.

With the above considerations before us it is questionable whether we should regard the use of chloroform before ether as a practice deserving widespread adoption. There are, nevertheless, circumstances under which this particular succession of anæsthetics is advisable. When we meet with such cases we should commence the administration of chloroform as has already been described, upon an open inhaler, in small quantities at a time; we should give the anæsthetic gradually but continuously; and we should replace it by ether at the

first signs of any mental or muscular excitement. In this manner we shall, at all events, avoid the second of the two risks above mentioned. No definite rules can be laid down as to the quantity of chloroform which should be given in any particular case. The chloroform must not on the one hand be removed too soon; nor must it on the other be withdrawn too late. Should it be given for a few seconds only, and the ether inhaler then applied, the patient, though perhaps not conscious of the change of vapour, may give trouble with swallowing, arrested breathing, coughing, etc. Should it be continued till deep anæsthesia has been produced, the risk which attends the stage of excitement under chloroform, and which might have been obviated had this stage been allowed to pass over under ether, would, of course, come into play.

For administering chloroform before ether the anæsthetist should be provided with a Skinner's mask and a drop-bottle for the former, and with a Clover's, Ormsby's, or Rendle's inhaler for the latter anæsthetic. If a Clover's apparatus be used, its indicator should be turned to "1" before being applied, and the strength of the vapour increased, as occasion may require, till the ordinary signs of ether anæsthesia result.

C. THE A.C.E.-ETHER SEQUENCE

For reasons which have already been fully considered, the A.C.E. and C.E. mixtures are less likely than chloroform to set up unsatisfactory symptoms during the induction period. It hence follows that such mixtures are well adapted for administering before ether.

This succession of anæsthetics is worthy of notice. The advantages which it possesses are:—Firstly, that the administration of the two agents is extremely simple, and requires no complicated apparatus; secondly, that no closely-fitting mask is used for commencing the administration; thirdly, that the initial sensations of the patient are by no means unpleasant; fourthly, that there is no alteration in the colour of the features during the induction of anæsthesia; fifthly, that tonic muscular spasm and temporarily embarrassed respiration are

very rarely met with, and, should they occur, quickly subside; and lastly, that the method seems particularly adapted for anæsthetising patients who are usually regarded as bad subjects for anæsthetics.

It is somewhat difficult to offer any adequate explanation of the satisfactory effects of the A.C.E. mixture followed by ether in those patients who are usually looked upon as unsatisfactory subjects. Tall muscular men, alcoholic individuals of both sexes, bloated and stout patients with every evidence of cardiac degeneration, asthmatics, and others who would almost certainly give some trouble not only with "gas-and-ether," but with ether administered by itself from a Clover's apparatus, will be found to pass into deep ether anæsthesia with remarkably little trouble if this method be carefully conducted. The A.C.E. mixture seems to supply exactly what is required for *inducing* anæsthesia in difficult cases; and ether, given from an Ormsby's inhaler, seems to be particularly well adapted for *maintaining* anæsthesia.

We must not forget that, as in all other methods, attention to certain points is indispensable if the administrator wish to give his patient no discomfort, and to prevent struggling and excitement—in a word, to successfully conduct the administration.

For successfully anæsthetising adult subjects, it is advisable to have at hand a piece of lint or a Skinner's mask (Fig. 47, p. 326), a Rendle's mask (Fig. 26, p. 270), and an Ormsby's inhaler (Fig. 36, p. 282). Clover's inhaler has in my hands proved far less satisfactory than Ormsby's for administering ether after the A.C.E. mixture to adult subjects. The mixture should be contained in a drop-bottle of the kind shown in Fig. 51, p. 327. I have found it of distinct advantage to employ lint or a Skinner's mask for the first minute or so, and then to go on with a Rendle's mask. But should the administrator wish for greater simplicity, he may conduct the administration with but one of these, preferably Skinner's mask, before proceeding to ether. The sponges of the Rendle's and Ormsby's inhalers should be wrung out in warm water, and the two inhalers, with their mouths uppermost, placed by the side of the administrator, ready to receive the A.C.E. mixture and ether. For anæsthetising children, a Skinner's mask, a drop-bottle for the A.C.E. mixture, and a Clover's inhaler will be found convenient. The intermediate (Rendle's) inhaler is not necessary.

Method of Administration (Adults)

1. *Apply the lint or Skinner's mask loosely to the face, and allow a few drops of the A.C.E. mixture to fall upon it.* The object of first employing lint or a Skinner's mask is to prevent all choking and uncomfortable sensations which might result from a closer inhaler.

2. *Gradually increase the quantity of the mixture upon the mask till the latter becomes more or less saturated.* The patient soon becomes accustomed to the vapour, and will be found to breathe it without the slightest difficulty. Should any hesitation in breathing occur, the mask must be held a trifle further from the face.

3. *After about one minute the Rendle's mask, upon the sponge of which about half a drachm of the mixture has been poured, should be applied.* The patient will probably not notice any change in the masks, and will continue to breathe without discomfort.

4. *Add more of the mixture (about half a drachm) from time to time, removing the mask for the purpose.* Whilst the administration is thus proceeding, the administrator should pour about half an ounce of ether on the sponge of the Ormsby's inhaler.

5. *In from two to four minutes from the commencement of the administration the Ormsby's inhaler may be very gradually applied.* I have met with two main guides as to the proper moment at which the change to ether should be effected : (1) deep and audible but non-stertorous breathing; and (2) commencing tonic contraction of the arms. In other words, the administration of ether should be begun at the commencement of the stage of rigidity and excitement. Any irrational talking, shouting, or singing may also be taken as indications that the change to ether may be effected.

6. *Apply the Ormsby's inhaler during an expiration, and do not at first press it tightly upon the face.* As a general rule the first inspiration is a trifle "held," and one or two acts of deglutition occur. In a few seconds, however, the patient

breathes in and out of the bag. The face-piece should now be tightly applied.

7. *Stertor and muscular relaxation now quickly appear.*

The administration should now be conducted as already described on p. 282.

The following case illustrates the effects produced by this succession of anæsthetics :—

Illustrative Case, No. 23.—M., about 35. One of the most powerful men I have ever seen. Chest measurement, 43 inches. Thick, large neck. Florid colour. A great athlete. Has lived well. Operation, radical cure of hydrocele. Duration, one hour. Administration begun at 9.50 A.M. with Skinner's mask. No holding of breath. When Rendle's mask applied there was occasional swallowing, but good respiration. Administration thus continued till breathing deeper. Changed to Ormsby charged with pure ether. More swallowing, and slight but not inconvenient movement of hand. Breath held very slightly. Some tonic spasm in neck and other parts, but no inconvenient movement. A breath of air given. Soon deeply snoring, but still a trifle rigid. At 10.20 pupils $2\frac{1}{2}$ to 3 mm., the right size for this particular case; they had been $3\frac{1}{2}$ mm. Very deep stertor. Pulse 114 : very full and bounding. Respiration 28 : regular, deep, and loudly stertorous. Stertor lessened by pushing jaw forward. Less ether allowed some tendency to crowing breathing, and made pupils *larger.* When operation over, less ether made pupils smaller. Vomited half an ounce of fluid material immediately after operation. No subsequent nausea.

Method of Administration (Children)

In anæsthetising little children (p. 116) with the A.C.E. mixture, followed by ether, all that is needed is to give the mixture on a Skinner's mask till respiration has become deep and regular, and then to replace the mask by a Clover's inhaler, with its indicator turned to about "1." Should the patient cry, the A.C.E. mixture may be administered till crying has nearly ceased, and the ether should then be applied. The following is an example :—

Illustrative Case, No. 24.—Patient a little boy, æt. 2 years 3 months. Florid. Breathes through mouth. Operation 10 A.M. : no food since previous evening. Semi-recumbent position. A few drops of A.C.E. mixture at a time on Skinner's mask. Some crying, but no resistance. After 1-$1\frac{1}{2}$ minutes Clover's inhaler previously charged with ether and turned to "1" applied. Anæsthesia in 2-3 minutes. Noisy

regular breathing: colour rather dusky: pupils 3 mm.: no lid-reflex: quite relaxed: pulse good and full. Total length of administration, including A.C.E. mixture = 5 minutes. Mouth opened by Mason's gag, and head arranged for good light to enter mouth. Tonsils removed by guillotine. Mouth sponged. No movement. Head and body now tilted forwards, and post-nasal space cleared of adenoid growths. Blood and detached growths came away from mouth and nose without slightest embarrassment to respiration. No sponging necessary. No movement. Operation, which lasted about 3-4 minutes, now over. Head kept forwards for drainage. Some cough and movement. Child turned on his side, in which position he lay quietly breathing, and with good colour for 10 minutes. Then began to cry and move about.

D. THE ETHER-CHLOROFORM SEQUENCE

This succession is frequently employed in practice. Thus, when ether is badly borne, when it fails to produce complete muscular relaxation, or when the parts involved in the operation are inconveniently vascular—in short, when any difficulty arises which appears to be dependent upon the use of ether—the recognised line of treatment is to change to chloroform. There are, however, other circumstances under which the ether-chloroform sequence may be employed. It may be chosen with the object of avoiding chloroform as an agent for *inducing* anæsthesia. We have seen (p. 342) that a large number of chloroform accidents have taken place during the initial stages of chloroformisation; and it is hence clear that if we *induce* anæsthesia by means of ether, and then continue it with chloroform, we shall very materially lessen the risks of the last-named anæsthetic. With such a system we shall have to reckon principally with the risks of chloroform when administered in toxic quantities—not with its risks during the earlier stages of anæsthesia. The ether-chloroform sequence, moreover, has certain other distinct advantages, the principal being that in long operations the patient is saved that saturation with ether which often paves the way for subsequent complications, and that, should any circulatory failure arise, the anæsthetist still has ether to fall back upon. It is true that, from the patient's point of view, ether is not a very satisfactory agent for *inducing* anæsthesia, but, as we shall see below, this objection may be overcome by employing

either the nitrous oxide-ether sequence or the A.C.E.-ether sequence instead of ether itself.

The most important point in connection with the ether-chloroform sequence is that it is necessary to be very careful as to the precise depth of ether anæsthesia when the change to chloroform is effected. *The change should not be made during struggling; nor should it be made, unless unavoidable, when signs of deep ether anæsthesia are present.* As a general rule, the conjunctiva should slightly sensitive to touch when the one anæsthetic is replaced by the other; but swallowing or coughing may also be accepted as an indication that the patient is not too deeply anæsthetised for the change to be effected. Unless these points be carefully borne in mind, a large and dangerous intake of chloroform may result, and toxic symptoms arise. There is also another point deserving attention in this connection. It is, as a general rule, good practice, before proceeding to chloroform, to allow the patient to cough out from his larynx any ether-mucus that may be present within it. If this be not done, laryngeal stridor, jaw-spasm, and other difficulties may be experienced throughout the chloroform administration. I have, in fact, notes of more than one case in which the presence of ether-mucus seemed to be the determining factor of respiratory arrest, the patient at the moment being deeply, but not dangerously deeply, under chloroform. Breathing does not cease from this cause when ether is given throughout, the respiratory movements being too forcible to be influenced by the slight obstruction.

E. THE NITROUS OXIDE-ETHER-CHLOROFORM SEQUENCE; THE A.C.E. (OR C.E.) - ETHER - CHLOROFORM SEQUENCE; AND THE CHLOROFORM-ETHER-CHLOROFORM SEQUENCE

These three sequences may be regarded as developments of those already discussed, and the advantages to be gained by their employment will be obvious from remarks already made. The nitrous oxide-ether-chloroform sequence is one which, perhaps, deserves most attention; for by its use as a routine

sequence for all ordinary surgical cases, nearly every possible requirement will be fulfilled. I have now employed this succession of anæsthetics for several years, and whilst admitting that it is hardly suitable for use by those who have had but little experience, I can confidently recommend it for others. The nitrous oxide prevents the unpleasantness of ether; it rapidly destroys consciousness; and cuts out the stage of excitement. The ether, when given after nitrous oxide, and by the "close" system, prevents struggling, and rapidly produces deep anæsthesia without subjecting the patient to that risk which attends the stage of rigidity under chloroform. And the chloroform produces a quieter and more manageable anæsthesia than ether; its use involves a smaller expenditure of nervous energy; it produces less local congestion; and it leads to less disagreeable after-effects. The nitrous oxide and ether should be administered as described on p. 407; whilst the change to chloroform should be effected in accordance with the principles laid down above (p. 418).

The A.C.E. (or C.E.)-ether-chloroform sequence and the chloroform-ether-chloroform sequence possess certain of the advantages just referred to; but they are open to the objection that they do not so satisfactorily prevent excitement and struggling.[1]

F. OTHER SEQUENCES

Clover, who, as we have seen, entertained a very favourable opinion of ethidene dichloride, used to precede the administration of this anæsthetic by nitrous oxide; but this sequence has never come into general use.

When ether does not produce a satisfactory form of anæsthesia, a change to the A.C.E. or the C.E. mixture will often answer well. Or, in certain cases, there may be reasons for inducing anæsthesia with the A.C.E. or the C.E. mixture and then changing to chloroform.

I have on several occasions produced deep anæsthesia by

[1] Mr. F. T. Paul of Liverpool (*Lancet*, vol. i., 1898, p. 679) states that it is his practice during chloroformisation to give a full dose of ether just before the stage of rigidity, and to subsequently resume the chloroform—in other words, he employs the chloroform-ether-chloroform sequence—and that the results are very satisfactory.

means of nitrous oxide and oxygen (p. 255) and have then proceeded to ether; but this particular succession has little if any advantages over the nitrous oxide-ether sequence already considered (p. 402).

Upon the Continent, bromide of ethyl has been to some extent employed immediately before chloroform[1]; but there are no special advantages in such a procedure.

Trélat, Forné, and other surgeons have recommended the administration of chloral before chloroform, giving from half to one drachm of the former drug about an hour before the inhalation of the latter. This plan, however, is now rarely if ever used, as it seems to increase rather than to diminish the risks of chloroform anæsthesia.

The use of morphine in conjunction with general anæsthetics will be considered in the following chapter.

[1] *Therapeutic Gazette*, 15th February 1894, p. 127. See also *Dict. de Physiologie*: Art. "Anesthésie."

CHAPTER XV

THE USE OF MORPHINE IN CONJUNCTION WITH GENERAL ANÆSTHETICS

In 1861 a case was reported by Pitha in which he succeeded in deeply anæsthetising a patient by the combined action of belladonna and chloroform, after chloroform itself had proved ineffectual. In 1863 Nussbaum[1] of Munich employed morphine in conjunction with chloroform, by injecting it *during* chloroform anæsthesia. He used from ·03 to ·06 grm. of the acetate of morphine, and found that patients thus treated remained in a deep sleep for a considerable time after the withdrawal of the chloroform, and then woke without nausea or vomiting. At about the same time Claude Bernard observed similar effects in dogs; and in 1869[2] published his researches.

MM. Labbé and Guyon[3] seem to have been the first to administer morphine *before* chloroform in surgical practice. They adopted this plan, not with Nussbaum's original object, viz. that of lessening the after-pain of operations; but with Claude Bernard's idea, viz. that of facilitating the action of chloroform, and rendering far smaller quantities of the anæsthetic than usual necessary. They injected morphine about 20 minutes before chloroform was given, and found that by this practice the excitement stage of chloroformisation was very considerably lessened, and that when once anæsthesia had been produced, extremely small doses of the

[1] The *Bavarian Med. Intelligencer* for October 1863 is stated to contain Nussbaum's paper. See also Kappeler, *op. cit.*; *Med. Times and Gaz.* vol. i., 1864, pp. 259 and 596; *Med. Times and Gaz.* vol. i., 1872, p. 350.

[2] *Lancet*, vol. ii., 1869, p. 789.

[3] *Med. Times and Gaz.*, 23rd March 1872, p. 359.

anæsthetic were needed to maintain insensibility to pain. In the same year Demarquay[1] drew attention to the special dangers which might arise from the combined action of the two drugs, and considered morphine contra-indicated, more especially in weak subjects. In 1877 Thiersch[2] employed the method in several operations about the mouth, and found it possible to maintain an analgesic state in which the patient, although unable to feel pain, could aid the operator by coughing out blood, etc., when requested to do so. Within more recent times other surgeons have advocated this preliminary injection of morphine. Thus, Dr. Alexander Crombie of the Bengal Army, writing in 1880,[3] stated that he had then employed it in 600 cases with excellent results. He advocated the injection of one-sixth of a grain immediately after the beginning of the administration of chloroform, and found that there was less vomiting than with chloroform alone, and that there was a striking absence of all asphyxial symptoms during the chloroformisation. Kappeler has devoted much attention to the subject, and by comparing the effects of chloroform without morphine and chloroform with morphine, in the same patient, on different occasions, concludes that the mixed anæsthesia is quieter, that the excitement stage is much shortened, that the patient is brought with less muscular action into the stage of "tolerance," that irregularities in breathing, leading to asphyxial symptoms, are conspicuously absent, and that much less chloroform is required. He finds, however, that vomiting is more frequent than with chloroform alone. Kappeler prefers to inject morphine 20 to 30 minutes before the chloroform is given, and uses in adults ·015 grm. and in children ·01 grm.

The use of morphine before chloroform has been found to be advantageous in cerebral surgery,[4] there being less vascularity of the brain and its membranes with this "mixed narcosis" than with chloroform alone. But as many of the patients requiring these operations may be at the time of the

[1] *Med. Times and Gaz.*, 21st September 1872, p. 334.
[2] *Lancet*, 8th December 1877, p. 861.
[3] *Practitioner*, December 1880, p. 401.
[4] *Brit. Med. Journ.* vol. ii., 1886, p. 670. See also p. 178 of present work

administration in a state of torpor or semi-coma, or may during the operation display symptoms of shock or respiratory depression, considerable discretion must be exercised in applying the method. Many surgeons, indeed, who at one time used this mixed narcosis, have now abandoned it in these operations.

Dr. Julliard of Geneva[1] advises the injection of one-sixth of a grain of morphine 20 minutes before ether is given. He very properly insists, however, that a preliminary trial of morphine some days before the operation should be made, in order to ascertain the patient's susceptibility to the drug. Dr. Julliard finds that patients are more quietly etherised after morphine than under ordinary circumstances. He also uses far less ether to keep up anæsthesia, and indeed in many cases is able to secure an analgesic effect. Curiously enough, Kappeler states that he met with many failures in giving ether after morphine, and with more excitement than usual.

Dastre, Morat,[2] and Schafer[3] have advocated the addition of atropine to morphine with the object of avoiding cardiac inhibition during anæsthesia, the atropine being given in doses of from $\frac{1}{100}$th to $\frac{1}{120}$th of a grain. But, as is pointed out elsewhere (p. 96), there is good evidence to show that the risk of cardiac inhibition during anæsthesia is far less than was formerly supposed, so that there is little or no need for any such precautions.

The use of morphine in conjunction with general anæsthetics has, in my hands, proved to be of most service in cases in which, for one reason or another, it would otherwise have been difficult to secure the desired degree of muscular relaxation and quietude. In the following cases the modifying influences brought about by the morphine will be sufficiently obvious:—

Illustrative Case, No. 25.—F., about 32. A cripple. Often has morphia for pain. Short and thin: rather anæmic: has been losing blood. Good heart-sounds and chest expansion. Quick pulse.

---

[1] *Op. cit.* See also *Brit. Med. Journ.* vol. i., 1891, p. 920.
[2] See Dastre, *op. cit.*
[3] *Brit. Med. Journ.*, 16th October 1880, p. 620. Also *Brit. Med. Journ.* vol. ii., 1880, p. 240.

Oöphorectomy lasting 1¼ hour. "Gas and ether" by Braine's meth. Put fairly well under "gas," but not as far as deep stertor. Considerable struggling during change to ether. (No remembrance of this on recovery.) Some delay in obtaining deep anæsthesia. Next day abdomen reopened. Temperature rising. Quick pulse. Precisely same plan of administration; but three doses of morphine (each ⅓ grain) had been given between first and second operations. Pupils small. Says feels drowsy. Skin moist. "Gas" given to same degree as before. Respiration became quieter than usual. *Change to ether not accompanied by slightest struggle or alteration in breathing.* Kept corneal reflex present. Pulse usually 1... 200. Operation ¾ hour. Very little ether needed. No attempt at coughing or retching. No secretion of mucus as on previous occasion. Respiration quiet.

Illustrative Case, No. 26.—F., 18. Acute peritonitis. Temperature 102°. Ill four days. ? Suppurating tube. Has been having half a grain of opium every three or four hours. Last dose two hours before operation. Florid-looking. Quick respiration. Nervous. A.C.E. (Skinner's mask and Rendle's). Soon breathing became slower and muscles flaccid. No resistance. Conjunctiva soon insensitive. Pupils contracted. Kept a slight conjunctival reflex. No vomiting or retching. No reflex of any sort. Regular breathing. Abdomen opened and offensive pus let out. No stridor. No movement or noise. Perfect anæsthesia. Good pulse and colour. Vomited slightly 10 minutes after she had been put back to bed.

Illustrative Case, No. 27.—M., about 25. A florid, athletic man. Tall. No hair on face. One-sixth of a grain of morphine 10 minutes before administration. Operation on septum nasi and turbinated bodies. Sitting posture. Gas-ether-chloroform sequence. No struggling. Slight rigidity. No difficulty. Kept slight corneal reflex as a rule. On one occasion his arm moved, and on two occasions his neck was slightly rigid. Laryngeal and pharyngeal reflexes preserved. Hæmorrhage free on two occasions, but distinctly less than usual, considering type of subject and nature of operation. No phonated sounds. Very good result. Pulse full and slow. Respiration deep and regular. Operation lasted 50 minutes. Left patient snoring in bed. No vomiting or retching throughout.

Illustrative Case, No. 28.—F., 62. Abdominal section for (?) gall-stones. Chloroform. When well under, so much laryngeal closure and consequent embarrassment of breathing that intra-abdominal manipulations were hardly possible. One quarter of a grain of morphine injected, and in 10-12 minutes condition improved. Deep chloroform anæsthesia needed, however, for rest of operation, which lasted 2½ hours. No respiratory depression. Good recovery.

Illustrative Case, No. 29.—M., about 46. A powerfully-built man. Have given him chloroform on two previous occasions; once for removal of half of larynx, and once for removal of further portion. On last occasion no tracheotomy tube used; lint much in operator's way; and somewhat troublesome cough throughout. To-day ¼ grain morphine 12 minutes before chloroform. Operation, suturing pharynx. In 3-4

minutes after administration begun, some rigidity of neck with half-open lids and distinct corneal reflex. Less struggling and rigidity than on former occasion. Found it possible to keep up anæsthesia by pumping chloroform vapour by means of Junker's inhaler *over* site of operation —a plan which would have been quite useless in the absence of morphine. Operation 1½ hour. Only coughed three times, and then not inconveniently. Great improvement in type of anæsthesia. Hands moved slightly once or twice, but not inconveniently. Respiration tranquil. Colour good. Pulse good. Very little hæmorrhage. Patient in dorsal posture with head extended. In this delicate operation great quietude was essential, and this could not have been secured (in such a subject during such an operation) by chloroform alone.

Whilst there can be no doubt that the use of morphine in conjunction with general anæsthetics is of distinct advantage in many cases, we must not lose sight of the fact that objections to the routine employment of this mixed narcosis undoubtedly exist. In addition to Demarquay, others have raised a warning voice as to the danger of employing opiates in conjunction with anæsthetics in certain cases. Dr. E. H. Jacob[1] of Leeds points out that there may be some risk in administering ether to patients already under the influence of an opiate, and cautions surgeons to be on the alert for this contingency when operating for hernia, as patients with that affection are often under opium at the time the anæsthetic is given. Mr. Clement Lucas[2] states that he has seen two cases of collapse and death after operations for hernia, and believes that the morphine was to a great extent answerable. These views are quite in accordance with those which I ventured to express in 1886. When writing in that year I was unaware that any attention had previously been directed to the dangers of the mixed narcosis. I then published[3] details of a case in which, during the operation for the removal of a cerebral tumour, the patient being at the time under the combined influence of morphine and chloroform, respiratory paralysis took place. The case possessed so many points of interest that I may perhaps be allowed to again refer to it.

Illustrative Case, No. 30.—M. K., a female patient, æt. 26, was admitted into hospital suffering from symptoms undoubtedly due to the

[1] *Brit. Med. Journ.* vol. i., 1881, p. 30. [2] *Ibid.* vol. i., 1882, p. 500.
[3] *Practitioner*, vol. xxxix., 1887, p. 93.

presence of a cerebral tumour. The day before the operation she could not be roused; her pupils were large, active to light, and equal; her pulse was 84; her respiration 18, and shallow; and she had right hemiplegia involving the face. On the day of operation she was quite unconscious; her respiration was 24, and somewhat noisy; and her pulse 100. One third of a grain of morphine was injected subcutaneously, and the administration of chloroform (diluted with one-fifth of ethylic alcohol) was commenced by means of Junker's inhaler. Slight coughing and feeble struggling were noted. Corneæ insensitive in about four minutes. Once only after this was it necessary to reapply the chloroform for a few seconds. One drachm of the anæsthetic was required altogether. When operation commenced pulse regular but weak, and respiration shallow. Forty minutes after the administration was begun breathing gradually ceased. Artificial respiration twice restored breathing for short time. One hour after administration commenced breathing ceased for third time, and could not be re-established. *Artificial respiration by Silvester's method was kept up continuously for four hours.* When artificial respiration was suspended, cyanosis ensued, and the pulse became feebler. About 2½ hours after administration commenced it was decided to attempt to complete the operation. This was successfully accomplished, artificial respiration being carried on the whole time. At the end of four hours automatic breathing returned, and the patient was moved off to bed.

It is difficult to say what was the actual cause of the cessation of breathing in this case. Whilst the anæsthetic may have been the exciting cause, it is obvious from the fact that artificial respiration had to be kept up for four hours before automatic breathing would return, that other more potent influences were at work, and amongst these the morphine probably held a prominent position.[1]

Since the case above related, I have seen others in which the use of an opiate before the administration of an anæsthetic has led to peculiar symptoms during anæsthesia. It is often possible, indeed, to tell from the manner in which the patient behaves under chloroform or ether that he has been taking morphine in some form or another. He passes with remarkably small quantities of the anæsthetic, and without any muscular spasm, into deep anæsthesia; his breathing is often abnormally slow; and unless very small quantities of the anæsthetic be used, respiration may become unexpectedly

[1] See also an interesting case in the *Dental Cosmos*, November 1895, p. 937. Nitrous oxide was given after ¼ grain of morphine, and respiratory paralysis ensued. Artificial respiration was successful.

npaired. Surgeons do not always acquaint the administrator ·ith the previous treatment their patients have received, and he anæsthetist should therefore be on his guard. In feeble nd exhausted patients, in those who are lethargic or semi-omatose, and in those with any respiratory difficulty, I am of pinion that the advantages obtainable from morphine are not ufficiently weighty to counterbalance the risks attendant upon ts employment.

In the two following cases, which appear to me worthy of)rief notice, the state of the patient *after* the operation seemed ;o be due to the effects of morphine given whilst the patient was still under the influence of the anæsthetic.

Illustrative Case, No. 31.—F., about 38. Peritonitis and intestinal obstruction of four days' standing. Abdomen much distended. Frequent vomiting. Rapid respiration, entirely thoracic. A.C.E. mixture given. Abdominal section. Operation lasted about an hour. Good colour at end of operation, and fair pulse. No tracheal râles. Twenty minutes later 40 minims of Tr. opii given by rectum. In 45 minutes patient cyanosed, and in great respiratory distress. Cheyne-Stokes breathing.[1] Patient propped up in bed. Breathing gradually became calmer, and in about two hours the duskiness had passed off.

Illustrative Case, No. 32.—M., æt. 19. Fair state of health. Removal of vermiform appendix. A.C.E. mixture given throughout, except for 15 minutes in middle of administration, when chloroform was used at the request of the surgeon. Duration of administration one hour and a half. Satisfactory anæsthesia. Respiration always quick. Pulse good. At end of operation ½ grain of morphine introduced into rectum: patient still well under anæsthetic. Swallowing movements came on, but no cough or attempt at vomiting. Respiration became extremely quiet. Could not rouse patient. Pupils moderately contracted. Colour began to grow dusky, but duskiness kept in check by flicking chest with towel and so stimulating respiration. Pulse rather feeble. He lay like this for 45 minutes, with no cough, although some mucus could be heard at back of throat. Some moaning and restlessness. Symptoms gradually subsided, and case did very well.

In the two last-mentioned cases I have every reason to believe that the opiate was the cause of the peculiar symptoms observed; for I have not met with such symptoms after anæsthetics when no opiate has been given.

[1] See "The Influence of Certain Drugs on Cheyne-Stokes Respiration," by G. A. Gibson, M.A. (*Practitioner*, vol. xxxviii., 1887, p. 85). See also "Two Cases showing Cheyne-Stokes Respiration in connection with the Administration of Chloroform and Morphine," by L. A. Parry, M.B. (*Lancet*, 18th January 1896, p. 161).

Several fatalities have been recorded in which the fatal symptoms were partly if not wholly due to the combined influence of the opiate and the anæsthetic.[1]

Should it be decided to administer morphine before chloroform or ether, the susceptibility of the patient to the drug should be previously ascertained. One quarter of a grain is generally sufficient, but somewhat larger doses may be needed in exceptional cases. The injection is best made about 20 minutes beforehand. The anæsthetic should be given till the usual signs of anæsthesia commence to appear. It should then be discontinued for a few moments, and only reapplied as occasion may require. As little as possible of the ether or chloroform should be subsequently administered; the conjunctival reflex should be retained; and an analgesic rather than a truly anæsthetic state aimed at. The objections which usually attend upon imperfectly-established anæsthesia do not apply with anything like their usual force when morphine has been given.

In administering an opiate, either subcutaneously or by the rectum, after the withdrawal of the anæsthetic, it is advisable to wait till the patient displays distinct signs of recovery from the anæsthetic. Should much mucus be present within the air-passages, morphine should be withheld till the mucus has either been coughed out or swallowed. It is needless to add that when any pre-existing respiratory affection is present, opiates should not be given.

[1] See *Med. Times and Gaz.* vol. i., 1867, p. 633; *Brit. Med. Journ.* vol. i. 1881, p. 69 (several cases quoted), and vol. i., 1882, p. 501.

PART IV

THE MANAGEMENT AND TREATMENT OF THE DIFFICULTIES, ACCIDENTS, AND DANGERS OF GENERAL SURGICAL ANÆSTHESIA

PRELIMINARY NOTE

It may seem to many that unnecessary stress has been laid upon this part of the subject. The reader must not imagine, however, that the numerous difficulties, accidents, and dangers about to be discussed are of such common occurrence as their detailed description might suggest. But seeing that troublesome and even threatening symptoms sometimes supervene in an unexpected manner, it behoves every one who gives an anæsthetic, even for the most trifling operation, to be fully conversant with the proper treatment that should be adopted. It has hence been thought desirable to go as thoroughly into the matter as possible.

CHAPTER XVI

MINOR DIFFICULTIES

In the preceding Parts of this work frequent reference has been made to the various difficulties, accidents, and dangerous conditions with which the administrator of an anæsthetic may possibly have to cope in the discharge of his duties. It has been pointed out that certain subjects are more prone to give trouble than others (Chap. VI.); that when some operations are in progress there is a greater tendency to the supervention of thereatening symptoms than when others are being performed (Chap. VII.); and that with each anæsthetic which has been discussed, special and peculiar phenomena of an inconvenient or possibly dangerous character may occasionally make their appearance. It will also be remembered that, when considering the preparation of the patient for the administration, reference was made to the few necessary appliances which should always be at hand for the treatment and removal of the various difficulties, accidents, and dangers which may complicate the administration (Chap. VIII.). But whilst the circumstances under which difficulties may occur are of the most varied description, the treatment to be adopted must be the same. It therefore appears to me to be most convenient to consider this branch of the subject from a general standpoint.

Whilst it would perhaps be misleading to emphasise the frequency with which troublesome cases present themselves in actual practice, it would be equally misleading were we to regard these minor difficulties as unimportant. By the careful observation of the patient's symptoms; by watching with an attentive eye for the slightest deviation from what may be called the normal course; and by correcting or relieving

symptoms which are in themselves but trifling, it is often possible to avoid difficulties and dangers of a serious or abiding character.

A. MINOR RESPIRATORY DIFFICULTIES

Patients sometimes give trouble by breathing in a hesitating and imperfect manner. Others hold the breath and refuse to breathe at all. With nitrous oxide, such difficulties may come about from tight-lacing, from the patient being ignorant of the manner in which he should inhale, or from sheer nervousness and apprehension. The remedy in each case is sufficiently obvious. With children, any crying or attempted rebellion should be met by continuing the administration, for in a few seconds anæsthesia must ensue. With other anæsthetics restricted breathing is often due to too strong a vapour; but even though a very dilute vapour be used, some patients will absolutely refuse to breathe freely. In such cases encouragement and reassurance should be brought to bear; and above all things, the administrator should never lose patience in dealing with the difficulties he has to encounter.

In some patients the breathing may remain hesitating and restricted after consciousness has been completely abolished. I have notes of two cases, indeed, in which actual cessation of respiration seemed to arise in this way. In one of these the patient was a hysterical young woman to whom nitrous oxide was being given; in the other A.C.E. was the anæsthetic, and the patient, a middle-aged man, who had obstinately refused to breathe, became so much asphyxiated that it was necessary to open his mouth and separate his tongue from the pharyngeal wall.

The other minor respiratory difficulties which may arise will be considered in the following chapter.

B. EXCITEMENT: MUSCULAR MOVEMENT: INCONVENIENT RIGIDITY

The various muscular phenomena which may be met with during the administration of anæsthetics have been fully con-

sidered (p. 54); and the reader is specially referred to the remarks already made.

The (1) uncontrollable "nervous" movements, the (2) conscious voluntary movements, and the (3) sub-conscious voluntary movements, do not as a rule give rise to any difficulties. The (4) unconscious excitement or intoxication movements, as well as (5) all tonic and (6) clonic movements, which are generally spoken of collectively as "struggling," may, however, be so pronounced that considerable difficulty may be experienced by the anæsthetist.

This is not likely to be the case with nitrous oxide when given by means of an accurately working and well-fitting apparatus; nor with ether when properly administered by the "close" system. But the faulty administration of nitrous oxide, the use of ether by the semi-open system, and, in certain subjects, the inhalation of chloroform in the usual manner, are one and all liable to be attended by shouting, gesticulation, violent muscular excitement, pugilistic movements, etc. When anæsthetising hysterical young women, hyper-sensitive persons of both sexes, alcoholic individuals, and those who have become addicted to morphine, chloral, etc. (p. 120), the administrator must be on his guard, and he should have assistance within easy call in case the patient should become unmanageable.[1] Excitement is often initiated by unnecessary restraint. Patients should never be touched or in any way held during the first few breaths of the anæsthetic. I have often known emotional disturbances started by merely grasping the hand of a partly-anæsthetised subject. Another frequent cause of excitement and struggling is the employment of too concentrated a vapour and too rapid an administration. As already indicated, great care is necessary in administering chloroform to hysterical subjects and others who breathe rapidly or struggle during the initial stages of anæsthesia (p. 349).

[1] I have fortunately only once failed to induce anæsthesia. The patient, a thick-set man of 46, was a great smoker, moderate drinker, and gave a history of having damaged furniture to the extent of £40 when a dentist endeavoured to anæsthetise him with nitrous oxide. I tried a gradual administration of A.C.E., but without success. I then attempted "gas and ether"; but this rapidly induced so much maniacal excitement that nothing could be done. There was a history of insanity in the family.

Should the patient's movements be such that he might possi do himself damage, or interfere with the administration, should be held by an assistant, but care should be taken n to lean heavily upon the chest or abdomen. As a gener rule, the cautious but continuous application of the anæsthet quickly causes such muscular phenomena to subside. Wit chloroform care must be taken, as has been fully explaine not to limit the air-supply during this so-called strugglin whereas with ether moderate air-limitation is advantageous this point, and free from risk in persons of average strengt With nitrous oxide a rapid increase in the supply of the anæs thetic is indicated, and greater pressure should be made up the face-piece in order that all air may be excluded.

Sometimes it is difficult to secure thorough and complete muscular relaxation during surgical anæsthesia, certain parts of the body remaining inconveniently rigid for a long perio Muscular and athletic patients, alcoholics of both sexes, and tall, dark, muscular men of nervous temperament, are par ticularly liable to give trouble to the anæsthetist by remainin inconveniently rigid. With nitrous oxide, as has been pointed out, muscular flaccidity can never be relied upon. With ether, too, there is on the whole a greater tendency to inconvenient muscular rigidity than with chloroform. Time should be allowed, when employing ether, for complete relaxation to become established. A patient may be rendered deeply un- conscious with this anæsthetic in a minute or two, but ten minutes or thereabouts may be required before thorough flaccidity can be said to be present. If rigidity persist after this period has elapsed—a most inconvenient condition in abdominal or bladder surgery—a few drops of chloroform should be administered upon lint; as a general rule the tonic spasm will then quickly pass away and the ether may be resumed. Rigidity will often disappear when more air is allowed, a fact which suggests that the condition may some- times depend upon intercurrent asphyxiation. I have known a widespread and inconvenient rigidity of the body coexist with an imperfect entry of air, from the tongue being pressed against the teeth: when, by the separation of the teeth, a more free passage of air became established, the rigidity at once

passed off. I have also noticed greater rigidity when employing narrow-bore ether inhalers than when using those of larger calibre (see p. 278). When attempting to overcome rigidity by means of ether, we should not only give large quantities of the drug, but also an increased air-supply. Whenever ether fails to relax, chloroform should be resorted to. I have come to the conclusion, however, that even with chloroform there are certain cases in which it is unsafe to push the administration to the point of complete abdominal relaxation. I have notes of several patients in which impairment of breathing and other signs of chloroform toxæmia have appeared just as I have been on the point of obtaining muscular flaccidity. Fortunately such cases are very exceptional. Curiously enough, there are certain remarkable cases in which full doses of ether will relax more completely than full doses of chloroform.

In one such case, that of a publican æt. 56, of heavy build, and with a large abdomen, I administered "gas and ether" and then changed to chloroform, but it was impossible to obtain complete abdominal relaxation. The operation was for appendicitis. I therefore again returned to ether, giving it freely from an Ormsby's inhaler, and the abdomen quickly relaxed. With the object of ascertaining whether the effect had been purely accidental, I again changed to chloroform; but the rigidity at once returned, so I was obliged to finish the case with ether.

In certain subjects and in certain operations it may be impossible to abolish all reflex movements without running the risk of administering an overdose. Neurotic and alcoholic patients are most liable to display exaggerated reflexes. Cutaneous incisions about the feet and legs, rectal, urethral, and vesical operations, manipulations within the peritoneal cavity, and the dilatation of any of the natural orifices of the body, are particularly prone to elicit reflex response, even during deep anæsthesia. Owing to the comparatively wide margin of safety with ether, this anæsthetic is specially indicated when it is desired to secure absolute immobility. Chloroform is, as we have seen, liable to bring about a state of false anæsthesia in which reflex movement may be very marked. It sometimes happens that the resources of the anæsthetist may be sorely taxed in attempting to abolish a particular

reflex. The following case, which has many points of interest, will make this clear:—

Illustrative Case, No. 33.—M., about 38. Fat. Very large thick neck. Full chin; much fat round angles of jaws. A heavily-built man. A perfect set of teeth. Suffers from pharyngitis. Slight cough. Nasal passages not very free. Drinks a bottle of brandy a day. Fairly good heart-sounds. Not nervous. Administration begun 10.10 A.M. No food since previous night. Varicose veins, both legs. Administration lasted 2 hours 20 minutes. A.C.E.-ether sequence (see p. 413). No excitement to speak of. Soon stertorous with ether, but muscles rigid and breathing rather embarrassed, so changed to chloroform (Skinner's mask). Found it necessary to keep Mason's gag in mouth, and tongue-forceps applied. Very narrow workable area. On the one hand (a) inconvenient reflex movement; slight phonation; breathing fairly free or only slightly obstructed by spasmodic retraction of tongue; slight or no corneal reflex; pupils variable. On the other, with more chloroform (b) slight reflex movement; greatly obstructed breathing — the tongue requiring forcible traction to overcome spasm; no phonation; no corneal reflex; slight duskiness; larger pupils. Difficulties augmented by presence of laryngeal mucus. Quick recovery from anæsthetic followed by heavy sleep.

In this case, which was an exceedingly difficult one, the choice lay between permitting reflex movements of the legs and bringing about a dangerous degree of obstructed breathing.

Clonic muscular phenomena and the curious movements (7) referred to on p. 56 must be regarded with suspicion when they arise under chloroform. They are liable to mislead the anæsthetist, who may mistake them for reflex movements and increase the anæsthetic; they call, however, for opposite treatment.

Fine rhythmic tremor (8) may be met with under all anæsthetics, but it is most common under ether. It chiefly affects the lower extremities, but it may be general. Muscular, nervous men, whose legs are exposed during the course of an operation, seem particularly liable to tremor. As a rule it may be stopped either by altering the position of the legs and feet, or by increasing the depth of anæsthesia. It is rare under chloroform.

C. COUGH

Coughing is always associated with a slight or moderate degree of anæsthesia; it never occurs in very profound narcosis.

In the early stages of the administration it may depend, as is sometimes the case when administering nitrous oxide, upon a long uvula which touches the pharynx. An alteration in the position of the head at once subdues the cough. Most commonly, however, at this stage coughing is due either to too pungent a vapour or to the presence of mucus and saliva within or about the laryngeal orifice. Patients with an irritable throat, and those who have recently smoked, are particularly liable to cough at the beginning of the administration. Speaking generally, coughing should be kept in abeyance, for it is likely to inconvenience the operator in most operations, and more especially in abdominal, ophthalmic, and bladder cases. If it be difficult to abolish cough when using ether, chloroform should be substituted; but great care must be exercised in effecting the change owing to the free intake of chloroform vapour during the deep inspirations between the coughs. As already explained, there are some cases in which an occasional cough is a positive advantage, for it keeps the air-passages free from blood (p. 148). In persons with much bronchitis, or with any affection accompanied by pulmonary or bronchial secretion, an occasional cough is to be encouraged. Coughing is nearly always preceded by deglutition-movements, so that, should the administrator desire to keep his patient free from cough, he should narrowly watch the behaviour of the larynx. The possibility of epistaxis and hæmoptysis taking place during anæsthesia must not be forgotten.

D. HICCOUGH

Hiccough seems to be most prone to occur when the intestines are being manipulated or operated upon. It is, however, very rarely met with. It is chiefly inconvenient during abdominal operations, and in cases requiring regularity and tranquillity of breathing. Unfortunately hiccough is difficult to relieve. It occurs with ether as well as with chloroform, and is little if at all influenced by modifying the depth of anæsthesia. I have notes of a case of gastro-enterostomy in which hiccough occurred and lasted half an hour. Chloroform was the anæsthetic. Directly Murphy's button was inserted and the stomach distension relieved, the hiccough disappeared.

E. RETCHING: VOMITING

Retching and vomiting, like coughing, never occur during very profound anæsthesia. They are met with either before true surgical anæsthesia has become established, or whilst the patient is emerging from the effects of the anæsthetic. It is the duty of the anæsthetist to do all in his power to prevent their occurrence whilst the patient is under his charge. Retching and vomiting are objectionable as complications of surgical anæsthesia for at least three reasons. In the first place, the movements of the patient's abdominal and thoracic parietes may embarrass the operator, or actually render the operation hazardous or impossible; in the next place, should there be food present in the stomach, its discharge during light or moderately deep anæsthesia may interfere with the administration, or endanger the life of the patient; and lastly, as already pointed out, there is with many anæsthetics, but more particularly with chloroform, a liability to syncope during the act of vomiting. To avoid the *contretemps* in question, the anæsthetist should give the anæsthetic as speedily as is compatible with safety, and should keep the patient deeply under its influence. An intermittent inhalation will be very liable to lead to swallowing, retching, and possibly actual vomiting.

Some patients are much more liable to retching and vomiting than others. The most liable appear to be tremulous and bloated patients of alcoholic habits; flabby young men and women with muddy complexions; and persons who are, as it is said, of "bilious temperament" or liable to "sick headaches." Persons of spare build, as well as the aged, are not nearly so prone to vomit as those of opposite types. When large quantities of mucus and saliva are secreted, a very deep anæsthesia may be necessary in order to stave off vomiting.

Retching and vomiting are very rare at the outset of an administration, though they may take place.

A curious illustration of this fact once came under my notice. A friend of mine wished to try the A.C.E. mixture, as I had explained that its vapour had a fragrant and agreeable odour when not concentrated. I poured *a few drops* upon the sponge of a Rendle's mask. The inhaler

had hardly been applied to the face before sudden vomiting occurred. Food had been taken just before the experiment. This was probably a purely reflex effect, produced by the contact of vapour with the mucous lining of the air-tract. I mention the occurrence because it serves, I think, to explain other cases, and because fright and apprehension were wholly absent, and could not therefore have contributed as factors. I also have notes of two other cases in which the A.C.E. mixture induced violent retching at the very outset of the administration. In one of these I had to abandon the mixture in favour of nitrous oxide. In the other a simple change of posture (from the dorsal to the lateral) was all that was needed. I have seen one case in which the inhalation of even a few breaths of nitrous oxide and oxygen caused such violent retching that the operation (dental) was impossible; and it became necessary to administer nitrous oxide and ether in order to obtain the necessary quietude.

Retching is not unfrequently induced, before administering an anæsthetic for a dental operation, by the simple opening of the mouth for the insertion of a suitable prop, or by the introduction of the prop itself. Nervous patients, great smokers, and alcoholic individuals are most prone to give this trouble. To overcome it the best plan is to divert the patient's mind by requesting him to mentally count his respirations whilst breathing the gas. In this way the difficulty may usually be surmounted. Should this fail, I find the plan suggested to me by Mr. R. H. Woodhouse to answer well. He employs a gargle of a rather strong solution of carbolic acid (about 1 in 100), after the use of which the patient can usually tolerate the presence of a mouth-gag without discomfort. Should these measures fail, a very small prop must be used, or the gas administered without employing any means for keeping the teeth apart. Under such circumstances as these, a Mason's gag must be introduced immediately the face-piece is removed.

When once the patient has been placed fairly under the influence of the anæsthetic, the administrator should have no difficulty in averting vomiting. He must watch for the early indications of its approach, and at once increase the depth of anæsthesia. Amongst these indications swallowing is the best guide. Sometimes, however, a high-pitched inspiratory sound may indicate a tendency to vomit; or a shallow form of breathing, with some pallor but with good conjunctival reflex, will be equally suggestive; or, lastly, an increase in the size of the pupil may help as a guide, though, if the administrator has

been on the alert, he will probably have received early warning from other signs.

When it is quite obvious that vomiting cannot be stopped the administrator should at once turn the patient's head to one side (if it be not already so placed), and raise the opposite shoulder. The teeth usually become clenched at this stage and little or no air enters the chest, as the larynx is, of course closed. The lower jaw should be pushed forwards from behind, and in a few moments the duskiness will pass off without difficulty. The mouth-opener shown in Fig. 9 (p. 19? may be very useful in separating clenched jaws during the act of vomiting. Should the patient be feeble it is not desirable to allow the breathing to become even temporarily suspended so that an endeavour should be made to expedite matters as much as possible.

F. SNEEZING

Sneezing occasionally, though rarely, occurs during anæsthesia. I have met with it chiefly in connection with intranasal operations. Should it fail to subside when the anæsthetic is pushed, it is best to spray the nasal passages with a dilute solution of cocaine. Sneezing may be so violent as to constitute a distinct difficulty, especially in delicate operations about the face.[1]

[1] See *Lancet*, 2nd and 16th Dec. 1893.

CHAPTER XVII

THE MANAGEMENT AND TREATMENT OF THE DIFFICULTIES, ACCIDENTS, AND DANGERS CONNECTED WITH RESPIRATION

SAFE and satisfactory anæsthesia can only be maintained so long as respiration is being efficiently performed. It is hence necessary to keep a vigilant watch for the slightest indications of respiratory feebleness or embarrassment, and at once to correct such conditions in order to prevent the occurrence of more serious troubles.

Having fully considered the various circumstances which may modify or interfere with respiration during surgical anæsthesia (pp. 42 to 47), the subjects in whom respiratory embarrassment is most common (pp. 122 and 123), and the different morbid conditions which may predispose to or directly cause arrest of breathing (p. 124 *et seq.*), we have laid the groundwork, as it were, upon which we may now construct a system of treatment capable of application to every case which may come under our care.

For our present purposes—that is to say, in order that the rational treatment of arrested breathing may be thoroughly understood—respiration may be regarded as a function whose efficient performance is dependent upon the proper working of (*a*) the respiratory pump, and (*b*) the respiratory centre. It is clear that each of these factors is as important as the other. An inexhaustible store of nervous energy will, for example, be absolutely useless should the air-way be occluded or lung expansion prevented, whilst the most patent air-tract and the most vigorous muscles will be equally useless in the absence of motive force.

We may thus say that there are two fundamentally distinct

forms of suspended breathing. The first of these (A) is due to some mechanical interference with the action of the respiratory pump, and, for the sake of brevity, will be termed *obstructive arrest of breathing*. The second (B) is due to depression of the respiratory centre, and may conveniently be termed *paralytic arrest of breathing*.

There are, moreover, three distinct ways in which obstructive arrest of breathing may take place. It may result (a) from occlusion of the air-tract, such occlusion being produced by altered position, spasm, or swelling of parts within or about the upper air-passages; (*b*) from the presence of some adventitious substance within the air-passages; or (*c*) from some condition which directly prevents lung expansion.

On the other hand, in paralytic cessation of breathing respiration simply comes to a standstill as the result of failure of nervous energy. In some cases (*a*) an overdose of the anæsthetic is the determining cause; in others (*b*) other factors are chiefly responsible.

Broadly speaking, the embarrassments in breathing which are dependent upon some mechanical interference with the free entry and exit of air take place during light or moderately deep anæsthesia, and are to be corrected by removing the obstruction or impediment which has led to the embarrassment; whilst those respiratory derangements which are dependent upon central, as opposed to peripheral, causes arise during deep anæsthesia, and are to be treated by artificially supplying the motive force which has become temporarily paralysed.

There is an interesting and important point which must be referred to in connection with occlusion of the air-tract. Given that, at the moment when occlusion occurs, the nervous mechanism of breathing is intact, and that there is no condition present which will directly interfere with lung expansion, futile and deceptive respiratory movements will for a time continue, and unless the anæsthetist be on his guard, they will be very liable to mislead him. As a general rule these movements are diaphragmatic rather than thoracic in type. The teaching of the Hyderabad Commission, viz. that the respiratory movements should be watched and taken as an indication of air entry, is highly erroneous. In order to be certain that respiration is

proceeding, the anæsthetist must either *hear* or *feel* each breath, except, of course, when he is employing a bag-inhaler, in which case the movements of the bag may be safely taken as a guide. Should breathing cease from some direct interference with lung expansion, this spurious and deceptive movement of the chest and abdomen will, as a rule, be completely absent, and the same is, of course, true of respiratory failure from central paralysis.

(A) Obstructive Arrest of Breathing

(*a*) Obstructive arrest of breathing dependent upon occlusion from altered position, spasm, or swelling of parts within or about the upper air-passages.

The importance of maintaining a free air-way during anæsthesia needs no comment. It is a curious fact, however, that very little attention has been bestowed upon this point. An anæsthetic is given, and the patient is said to "take it badly" or to "breathe badly," but the cause of the difficulty in breathing is rarely accurately defined. There is a tendency for all anæsthetics to indirectly or directly cause occlusion of the upper air-passages, and this tendency is greater in certain types of subjects than in others. The different effects produced by this or that anæsthetic are, in fact, frequently to be explained by differences in the calibre, conformation, and sensitiveness of the air-tract of the particular patient. Obese and plethoric subjects, those who have smoked or drunk to excess, and muscular men with good teeth and powerful jaws, are particularly liable to this occlusion; and when we find, in one patient, a combination of several factors, each of which may of itself give rise to difficulties, the occlusion may readily culminate in threatening or even fatal asphyxia. Moreover, in addition to the fact that certain types of healthy human beings are specially liable to self-asphyxiation during anæsthesia, we must bear in mind that there are other subjects who, by reason of the presence of certain morbid conditions, are equally liable to such complications (see pp. 124 and 126). The very worst subjects are those who, in addition to belonging to unfavourable types, are suffering at the time of administration

from some condition (such, for example, as that of angi[na] Ludovici) which is itself obstructing and hampering respirati[on]. (See Illust. Case, No. 16, p. 393.)

Sometimes, especially in edentulous subjects, the **lips fal[l] together** and occlusion results. Or the lips may becom[e] pursed up, with a similar result. In either case the reme[dy] is sufficiently obvious.

We have already seen that **stertor** always indicates som[e] degree of occlusion; and the various forms of stertor whic[h] may be met with during anæsthesia have been fully considere[d] (pp. 45 and 46).

Respiratory arrest from **alteration in the position of parts**

FIG. 55.—The Finger of the Administrator pushing the Lower Jaw forwards.

within the upper air-passages may sometimes be seen during deep anæsthesia, when a patient is turned from the lateral into the supine posture, the flaccid tongue at once falling over the glottis. Similarly, pedunculated growths of the epiglottis or naso-pharynx may, in certain postures of the body, bring breathing to a standstill. In each case the treatment is simple and self-evident.

As has been frequently pointed out in preceding pages, **muscular spasm** is a fruitful cause of occlusion, for it may come into play at several points within the upper air-tract. In a large percentage of surgical cases it is necessary to counteract this tendency to spasmodic closure of the air-way by keeping the lower jaw pressed forward from behind (Fig. 55). This procedure has the effect of bringing the base of the tongue and the epiglottis away from the pharyngeal wall, in

which situation they are often held by muscular spasm. By means of the laryngoscope it is not difficult to demonstrate this recession of the epiglottis from the pharynx when the lower jaw is pressed forward. Should there be much masseteric spasm and stertor, it is sometimes necessary to push the lower jaw forwards from both sides before breathing will freely take place. In some cases, moreover, the front teeth, by overlapping the lower, prevent the lower jaw coming forwards, so that the teeth must be disengaged before breathing can be re-established. Under such circumstances as these the insertion of a small mouth-prop may be advantageous; but it is important to adjust the prop in such a way that the lower jaw may ride forwards upon the upper. The best plan is to place the prop of Fig. 10 (p. 199) between the *back* teeth so that it acts as a roller (Fig. 56). If it be inserted as in Fig. 57, between the *front* teeth, it may be impossible to move the lower jaw forwards, and respiratory embarrassment may increase rather than diminish. There are certain cases in which breathing will not proceed when the mouth is opened, the explanation being, as Dr. Bowles has pointed out,[1] that the base of the tongue is thrown against the pharyngeal wall, and in such it will be necessary either to use a very small prop or to dispense with one altogether.

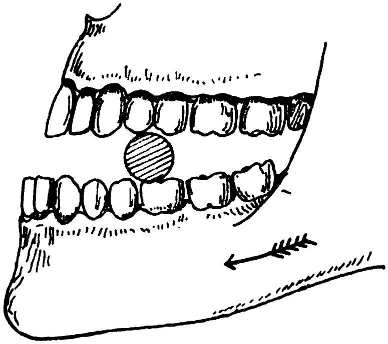


FIG. 56.

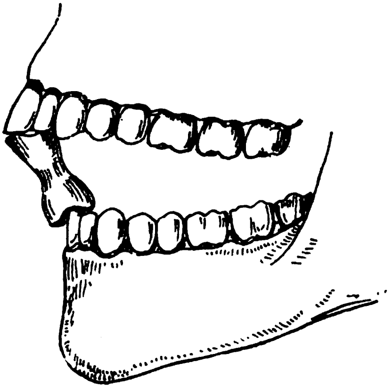


FIG. 57.

[1] *Op. cit.*

Pulling the chin away from the sternum,[1] or completely extending the head over the end of the operating-table, is often of use in the treatment of obstructed breathing, the beneficial effects being due to recession of the epiglottis from the laryngeal orifice. I have in more than one case heard a distinct sound such as might be made by the sudden opening of the larynx, at the moment of extension, and respiration has at once recommenced. The extension is most likely to be of use in patients with free nasal passages and thin necks. In thick-necked, muscular subjects with nasal obstruction, extension of the head will of itself be useless as a remedial measure. In conjunction, however, with disengaging the teeth and pushing the lower jaw forwards, as above described, the extension is often distinctly valuable.

In the event of the foregoing treatment proving unsucessful, the mouth must be opened, a Mason's gag inserted, and the finger passed to the back of the throat to separate the tongue and epiglottis from the pharynx. The mouth-opener of Fig. 9 (p. 199) will be found very useful on such occasions as these. Temporary arrest of breathing is frequently due, as Clover pointed out, to partially performed deglutition; and the presence of the finger-tip within the pharynx will often lead to a completion of the act of deglutition and so to renewed respiratory action. Should breathing still remain suspended, however, the tongue-forceps must be applied, and vigorous traction made; and in the vast majority of cases this measure will quickly have the desired effect. Should it not succeed, the chest must be forcibly compressed with the object of overcoming the occlusion by increased intra-thoracic pressure.

In addition to laryngeal closure from partially performed deglutition, we have seen (pp. 46 and 351) that the larynx may become obstructed in two other ways, viz. from collapse of the

[1] This was recommended by Clover, as a useful procedure, as far back as 1874. See *Brit. Med. Journ.*, 14th February 1874, p. 201. Mr. Clover made the following important remarks:—"The act of swallowing is usually performed well enough; but, if the anæsthetic have produced sufficient effect upon the patient to interfere with reflex movements, then the deglutition may be delayed at the moment when the epiglottis covers the larynx. Raising the chin, and pulling it as far as possible away from the sternum, is usually sufficient to obviate this source of obstruction."

arytæno-epiglottidean folds, and from spasm of its sphincter muscles. In all forms of laryngeal occlusion the treatment is practically the same. Minor degrees should be treated by suspending the anæsthetic, briskly rubbing the lips, and pushing the lower jaw forwards. When the spasm is dependent upon the local irritation of mucus, it is usually best to allow the patient to regain his swallowing and coughing reflexes, and the spasm will quickly subside. As a general rule, laryngeal spasm is met with during moderately deep anæsthesia. Generally it is best to lessen rather than to increase the depth of narcosis. In obstinate cases, when the stridor becomes more and more intense, and increasing cyanosis testifies to the deficient air-entry, it may be necessary to open the mouth and vigorously apply the tongue-forceps. Lord Lister has urged the importance of this prompt treatment when laryngeal occlusion takes places under chloroform; and he believes that tongue-traction acts reflexly in opening the larynx. Should it not succeed, artificial respiration may be tried, but is not likely to be successful. It is certain that tongue-traction does not directly bring the epiglottis away from the larynx, as was at one time believed. I have never known true laryngeal spasm to completely arrest respiration under ether. In fact, I have notes of several cases in which a change from chloroform to ether has caused the spasm to at once subside. The condition is most common under chloroform.

The measures above described will generally succeed in opening an occluded air-tract, but in certain cases (which are fortunately highly exceptional) they will fail; and under such circumstances laryngotomy must be performed. To those who have had but little experience it might seem that this treatment could only be justifiable for the relief of obstruction dependent upon the presence of adventitious substances or morbid states; but such a view is erroneous. When certain factors combine, it may be impossible to overcome the occlusion by any other mechanical means. When, for example, the neck and throat muscles of a powerful and obese subject are thrown into a state of intense spasm, and when the tongue, fauces, laryngeal folds, and other adjacent

structures become so engorged and swollen that the air-way is completely closed, nothing short of laryngotomy may be of any avail. In such subjects deep stertor is, as we have seen, very common; it readily passes into occlusion; general asphyxial spasm results; and the last straw is furnished by swelling from general venous engorgement.

In the event of laryngotomy failing to re-establish breathing, artificial respiration by Silvester's method (*vide infra*) must be immediately commenced, and in the vast majority of cases in which remedial measures have been carried to this point recovery will take place. But in certain cases the asphyxial condition present—a condition originally brought about by an occluded air-tract—gradually or rapidly becomes characterised by so much *general* respiratory spasm that even though an opening has been made into the occluded passage it may be impossible to set the respiratory pump going by the usual means. As we shall see when discussing respiratory spasm as one of the conditions capable of directly preventing lung expansion (*vide infra*, p. 463), the remedy to be adopted in such cases is lung inflation through the laryngotomy tube.

It is in cases of this class that venesection is likely to be of use, but it should only be resorted to as a secondary measure, the main chance lying in quickly obtaining an entry of air to the lungs. The immediate cause of death in these cases is cardiac failure due to over-distension of the right cavities,[1] and venesection is hence indicated.

It is probable, too, that lowering the feet (p. 93), by bringing the patient's body *across* the bed or table, is advantageous; but here again such treatment must not be allowed to interfere with artificial respiration.

The following illustrative cases may perhaps be of interest:—

Illustrative Case, No. 34.—M., æt. about 22. Pale: neck much enlarged both sides by sub-maxillary glands: no nasal respiration, probably from presence of adenoid growths. Operation for removal of

[1] Venesection was practised by Dr. John Reid in the treatment of asphyxia (see Johnson's *Essay on Asphyxia*). See also an interesting case of drowning reported by Mr. J. F. Briscoe (*Brit. Med. Journ.*, 23rd September 1899), in which venesection apparently saved the patient. The venous engorgement was so intense that retinal hæmorrhage and temporary blindness occurred.

rvical glands. Teeth kept apart by preliminary insertion of small ece of cork. Ether administered by Clover's inhaler. Respiration fficult. Unable to keep lower jaw pressed forwards by reason of its ing deeply embedded in the glandular swelling. Tongue much igorged. A.C.E. mixture tried : no better result. The difficult respiraon obviously depended upon the tongue obstructing the oral air-way. ad to keep base of tongue hooked forwards by finger. Eventually had keep tongue pulled continuously forwards by means of tongue-forceps, id to administer chloroform on the end of a Skinner's mask. By this ieans respiration became free and all difficulty vanished. Administration sted one hour.

The above case illustrates the impossibility, in some intances, of pushing or dragging the lower jaw forwards. The ifficulty of breathing was due to this cause, for the base of he tongue rested against the pharynx and could not be rought away by the usual means.

Illustrative Case, No. 39.—F., æt. about 35. Healthy in appearnce. Good chest expansion. Quick but good heart's action. Operaion for ruptured perineum. Duncan and Flockhart's chloroform : rop-bottle : Skinner's mask. In 7 to 9 minutes from commenceient of administration pupils moderately contracted (about 2½ mm.), reathing quiet and non-stertorous, pulse and colour good. Operation ommenced. On several occasions high-pitched crowing inspiration was ioted, even though corneæ insensitive and patient apparently well under. The difficulty was overcome by giving more chloroform and pushing ower jaw well forwards. On one occasion, however, this plan failed, ind the mouth had to be opened and tongue-forceps applied. This restored breathing, but the colour remained pale and dusky afterwards. Ether now given on an open inhaler. Pulse and colour gradually improved, and satisfactory anæsthesia was maintained without any difficulty or half an hour. The operator found, however, that the parts were far nore vascular under ether than under chloroform, so the latter anæshetic was again tried. Precisely the same respiratory difficulty as efore appeared. The operation, however, was by this time just finished. The crowing breathing subsided altogether directly the manipulations ibout the perineum were discontinued.

The above case is of considerable importance as illustrating the occurrence of what may be termed reflex laryngeal obstruction during the use of chloroform. Florid young and middle-aged adults seem particularly liable to the condition under chloroform during such operations as that mentioned, and the only treatment which is of any avail in obstinate cases is forcible tongue-traction.

Illustrative Case, No. 36.—M., æt. about 40. Bloated, fla[illegible] and very alcoholic. Short stature, short neck, large abdomen. Ex[illegible]tremely nervous and tremulous. The lower jaw embedded, as it w[illegible] in thick flabby tissues, the patient having a "double chin." Good te[illegible] Operation, removal of small tumour in mammary region. Decided [illegible] administer ether preceded by a small quantity of the A.C.E. mixt[illegible] (See p. 413.) A.C.E. given gradually on Rendle's mask. Respira[illegible] good. No struggling. Some rigidity coming on, Ormsby's inh[illegible] charged with "pure methylated ether" was applied gradually. Resp[illegible]tion at first fairly free, but in a short time some spasm about the [illegible] came on, and rather suddenly drew the head somewhat forwards so th[illegible] the chin approached the sternum. This at once stopped breath[illegible] Could not press jaw forwards from behind owing to thick neck: a[illegible] forcible extension of the head and neck equally impossible becau[illegible] extreme muscular rigidity. Mouth opened: Mason's gag introduce[illegible] and forcible tongue-traction made. Respiration at once became [illegible] established, and normal colour of face returned. No further diffi[illegible] beyond that great care had to be exercised to keep an air-way open.

The above case illustrates the difficulties which may ari[illegible] in anæsthetising a patient of the type described, and t[illegible] manner in which such difficulties should be treated. N[illegible] matter what anæsthetic be chosen, fat and flabby subjec[illegible] presenting the appearance I have attempted to portray, w[illegible] always be liable to give trouble to the anæsthetist during th[illegible] stage of muscular spasm. The sudden arrest of breathin[illegible] (before the patient was really properly anæsthetised) wa[illegible] doubtless due to spasm of some of the neck and jaw muscle[illegible] such as the sterno-mastoid, mylohyoid, etc., the contractio[illegible] of which suddenly brought the head forwards and the chi[illegible] downwards, thus throwing the base of the tongue against th[illegible] pharyngeal wall. In patients of a different type from that described, the obstructed breathing may at once be corrected by the procedure figured on p. 444, by pulling the chin away from the sternum, or by extending the head and neck. But in certain individuals neither of these procedures may be possible, and tongue-traction will hence become necessary. Subsequent experience has led me to believe that in patients of the type here referred to ether is best avoided.

Illustrative Case, No. 37.[1]—M., æt. 35. Middle-height: we[illegible] nourished: rather florid. Present general condition good, but has b[illegible]

[1] I published this case in detail in the *Journ. Brit. Dent. Association* for 1888, vol. ix. p. 222.

any rheumatic attacks which have left him with articular disease id stiffness in many parts of body. Neck rigid. Can only open outh about one quarter of normal extent owing to chronic rheumatoid sease of articulations of jaw. Nitrous oxide administered for tooth :traction. Usual method adopted. Small mouth-prop inserted before .ce-piece applied. The usual phenomena of nitrous oxide narcosis resented themselves. Tooth extracted. The nitrous oxide had been ushed till respiration underwent the characteristic change in rhythm; ut the admission of air which followed the removal of the face-piece iiled to restore the rhythm of breathing. Instead of respiration becom-ıg re-established and the normal colour returning, breathing became ıore difficult and quickly ceased as if from some obstruction. It was ıpossible to push the lower jaw forwards because of its fixity, or to xtend the head and neck owing to the rigid and ankylosed spine. The ınger could not be passed to the back of the throat by reason of the mall aperture between the teeth. Tongue-traction was at once made, ›ut failed to restore breathing. Compression of the thoracic walls was :qually unsuccessful. The patient was placed upon the floor and forcible ›ressure was brought to bear on the sternum, but the thorax was immov-ıble. The face was cyanosed and bloated, the lips purple, the whole ›ody rigid, the chest motionless and fixed. Breathing had been sus-pended for about 2 or 2½ minutes, according to my reckoning; but it is lifficult to speak positively on this point. It was obvious that the only remedy left was laryngotomy. Having my tracheotomy instruments with me I rapidly opened the crico-thyroid membrane with a pocket-knife and inserted a tube. Breathing at once recommenced. The patient made an uninterrupted recovery.

I have introduced the above case as it is of considerable interest. The obstruction to breathing was almost certainly at the superior aperture of the larynx. As has been shown (p. 220), when nitrous oxide is administered to its full extent, the larynx is often drawn up, as in deglutition, to meet the epiglottis. Should the temporary obstruction thus brought about not pass off spontaneously, as it usually does, all that is necessary in ordinary cases is to push the lower jaw well forwards from behind, which brings the epiglottis away from the larynx and restores breathing. But in this remarkable case this manœuvre was impossible, owing to the almost complete fixity of the jaw. Traction upon the tongue was equally unsuccessful; for, as we have seen, the epiglottis cannot be moved in the slightest degree by pulling the tongue forwards. The narrow space between the upper and lower teeth prevented the finger from being introduced with the object of removing the epiglottis. And lastly, the cervical spine being

ankylosed, the head could not be extended. Had it been possible to completely extend the head and neck, the obstruction would probably have been overcome. Laryngotomy was fortunately successful in rescuing the patient from imminent death.

(*b*) **Obstructive arrest of breathing dependent upon the presence of adventitious substances within the air-passages.**

There are numerous adventitious substances, both liquid and solid, which may find their way into the air-passages during anæsthesia and give rise to respiratory difficulties. Amongst them may be mentioned:—

1. Blood.
2. Vomited matters.
3. Mucus.
4. Pus.
5. Portions of morbid growths.
6. Extracted teeth, fragments of teeth, or stoppings.
7. Artificial dentures and pivoted teeth.
8. Portions of or entire mouth-props or corks.
9. Portions of instruments used in laryngeal, dental, or similar operations.
10. Pieces of sponge not firmly secured upon holders.
11. A "quid" of tobacco[1] which was present in the mouth before the administration has also been known to cause asphyxial symptoms during anæsthesia.

Blood may enter the larynx, trachea, or bronchi, either as the result of some surgical procedure about the air-passages or as a consequence of hæmoptysis or epistaxis.[2] The two last-named conditions are very rare, but it is nevertheless necessary to bear in mind the possibility of their occurrence. With regard to the entry of blood into the larynx, trachea, or bronchi, as the immediate result of some surgical operation, it is

[1] Fischer, *Deutsche Zeitsch. f. Chir.* Bd. xv. 188.

[2] I have met with one case of epistaxis under ether, in a young man of about 24. In Dr. Sheppard's notes I find another case recorded in which epistaxis occurred under chloroform. In the latter case the patient was a man of 62, and the epistaxis came on after struggling. A moist râle in the trachea was the first indication of the bleeding. On looking into the mouth a good deal of clotted blood was discovered. Hæmoptysis is very rare. I have never met with it, though I know of one case in which it occurred, to a slight extent, under ether.

.ear that the invasion may take place either from above or elow, and the symptoms displayed by the anæsthetised patient 'ill naturally vary with his general state, the posture, the depth f anæsthesia, the quantity of blood present, and the natural egree of sensitiveness of the air-tract.

In operations within and about the mouth, nose, and throat, mall quantities of blood frequently gain access to the larynx nd trachea; but, as a general rule, such quantities do not ive rise to any serious symptoms either at the time or subse-uently; for when the anæsthetic is withdrawn, swallowing nd coughing return and the breathing and colour quickly ecome normal in type. But if, during such operations, the ules to which reference has already been made (p. 148) be lisregarded, and if hæmorrhage be free, obstructive symptoms nay come about either gradually or with remarkable sudden-ness, and the anæsthetist may find himself face to face with a very alarming state. Should it be necessary to keep up a fairly deep anæsthesia, and should the posture be such that blood cannot flow freely from the mouth, frequent sponging as already described (p. 151) must be practised, the middle finger being used in preference to any sponge-holder. The sponges employed should be, when moist and expanded, about half the size of the patient's fist, and it is important that they should be coarse and free from loose pieces. New sponges which have been allowed to soak in 1 : 20 carbolic lotion and then washed in boiled water should be used, and it is best to have half-a-dozen of such sponges at hand. I was once able, by using a sponge of this kind, to entangle in its coarse meshes, and so remove from the larynx and trachea, a clot which measured over four inches in length. In cases of this class a careful watch must be kept for any moist expiratory râle—the first sign that the larynx and trachea are being invaded by an undesirable quantity of blood—and should this râle become audible the anæsthetic must be at once suspended and repeated sponging practised. In some cases the breathing comes to a standstill so quietly that the true nature of the arrest may not be recognised. In gradually increasing obstruction, however, a râle is audible, and progressive cyanosis usually occurs. Should the larynx be naturally insensitive, the

hæmorrhage free, and the anæsthesia deep, blood may sudden[ly] invade the air-passages and breathing cease with little or [no] alteration in colour. Should the withdrawal of the anæsthet[ic], assiduous sponging, and attention to posture prove unsuccessf[ul] in removing blood from the larynx, the chest and abdom[en] must be forcibly compressed. As a general rule, this w[ill] succeed in expelling blood, but should it not do so, the patie[nt] must be partially or completely inverted and systematic art[i]ficial respiration performed, care being taken to keep the tee[th] apart and the tongue pulled forwards. Should these measur[es] fail, laryngotomy must be performed, artificial respiration renewed, and, if necessary, a catheter introduced into the trachea with the object of sucking out the obstructing flu[id]. Lung inflation through the laryngotomy wound may also be tried should artificial respiration fail to effect an entry of air.

During operations upon lung cavities blood may enter the bronchi, and under certain circumstances obstruct breathin[g]. The following interesting case may be quoted :—

Illustrative Case, No. 38.—M., about 45. Has been very ill [for] several weeks. Thin. Orthopnœa. Dusky. Prominent eyes. Anxious and nervous expression. Quick respiration. Pulse feeble and quick—about 160. Air enters right lung fairly freely. Left side dull and immobile, with amphoric breathing at base. Operation, resection of r[ib] and draining lung cavity. Lies more easily on right than on left side; but sitting posture most comfortable. Placed partly on right side and partly sitting. A.C.E. mixture given slowly, and then a little ether added to Rendle's inhaler. Breathing quick and somewhat more laboured. Deep anæsthesia impossible. Offensive pus evacuated. Some hæmorrhage. Rib excised. Drain inserted. During operation a coarse râle became audible, and though anæsthesia light, colour became more dusky. Placed patient on *left* side in order to keep better lung free from blood and pus. A coarse râle palpable over right lung. Dusky. Pulse very quick and weak. Strychnine injected. Enema of brandy. Brisk corneal reflex but asphyxial state persisted, and still unconscious, though no anæsthetic had been given for a considerable time. As condition did not improve I inserted gag and tickled epiglottis and fauces with finger. This induced cough, and a sponge in fauces now extracted a clot obviously coughed up from right bronchus. Immediate improvement and quick return of consciousness.

[1] For illustrative cases see *Brit. Med. Journ.*, 24th Feb. 1883, p. 352 (two fatal cases recorded). Also *Lancet*, 27th Aug. 1881, p. 386. Also *Brit. Med. Journ.*, 16th Sept. 1882, p. 531 ; and *Lancet*, 30th Sept. 1882, p. 540.

The above case is a very good example of intercurrent sphyxia. Symptoms such as these are often erroneously scribed to the anæsthetic or to "shock."

Vomited Matters.—Numerous cases are on record in vhich, during anæsthesia, vomited matters have been drawn nto the larynx and trachea, and have thus caused fatal sphyxia.[1] As we have already seen, vomiting is of very ommon occurrence with most anæsthetics; and should the tomach contain undigested solid food there is always some isk connected with the expulsion of the contents of this organ. A proper regulation of the diet is not always possible, and here are, moreover, certain cases, *e.g.* those of intestinal obstruction, in which vomiting is a feature of the malady for which an operation is needed. In such cases every care must be exercised by the administrator. The head should never be permitted to pass into the mid-line; it must be kept upon its side throughout. In the case of heavily-built or obese subjects the opposite shoulder should be raised by a pillow; and a Mason's gag inserted in order to allow of the fauces being rapidly cleared, should occasion require. Unless these precautions be taken, the administrator may suddenly be confronted by an alarming condition—the mouth and nose being full of vomited matter, the jaws tightly clenched, the neck rigid, the breathing completely arrested, and the patient cyanosed. Not only is it difficult to re-establish breathing under such circumstances, but there is a considerable risk of asphyxial syncope, especially when chloroform has been used and the patient's heart is dilated or feeble.

The treatment to be adopted in all cases in which the vomiting of solid or fluid substances takes place is to clear and re-establish the air-way as speedily as possible. The mouth must be opened—if necessary with the mouth-opener—a Mason's gag inserted, the head and shoulders turned well

[1] Of the 101 chloroform fatalities reported by Kappeler two were due to this cause. For Illustrative Cases see *Lancet*, 30th Sept. 1871, and *Brit. Med. Journ.*, same date; *Edin. Med. Journ.* vol. viii.; two cases reported by Socin in the *Tageblatt der Naturforscherversammlung*, 1879, No. 7; *New York Med. Journ.*, 20th Oct. 1883, p. 448 (two cases referred to); *Lancet*, 3rd Oct. 1874, p. 504; *Brit. Med. Journ.*, 16th Sept. 1876, p. 381; *Brit. Med. Journ.*, 24th Feb. 1883, p. 351; *Brit. Med. Journ.*, 3rd Sept. 1881, p. 414. A case is also referred to by Dr. Jacob in the *Brit. Med. Journ.*, 23rd Feb. 1884, p. 351.

to one side, and the fauces cleared with the finger or sponge. Should the finger be able only to touch the intruding substance, a pair of curved forceps may be used with advantage. If the breathing become seriously impeded, and if the above measures fail to restore it, an attempt should be made, by compressing the sides and front of the chest, to force air past the obstruction. If, however, artificial respiration should fail laryngotomy must be resorted to.

Mucus and Saliva.—Children and adolescents often secrete considerable quantities of these fluids, particularly during ether anæsthesia; and respiratory difficulties may in consequence arise. These difficulties may either be dependent upon (a) simple mechanical obstruction to the passage of air; (b) the mucus and saliva exciting cough, partially performed acts of deglutition ("holding the breath"), retching, or vomiting; or (c) laryngeal spasm induced by the local agency of the abundant secretions. Should profuse salivation occur during the administration of nitrous oxide for a dental operation, the head should be kept quite vertical, or even be bent forwards, till the face-piece is removed, when it may be replaced in the posture desired by the operator. In general surgical practice, *i.e.* with other anæsthetics, it is advisable to keep the head turned well to one side and the dependent cheek frequently wiped out. Should the breathing become in any way obstructed by the excessive secretions, the fauces may be sponged out from time to time. In cases in which the act of coughing would not inconvenience the surgeon, the patient may be allowed to regain his reflexes to this extent, in order to free the air-way. As already pointed out (p. 46), laryngeal spasm, known by a high-pitched inspiratory stridor, is often dependent upon the presence of mucus, and the anæsthetist will find it an exceedingly difficult matter, particularly in abdominal cases, to safely steer his patient through a profound chloroform anæsthesia with laryngeal spasm present. Laboured breathing, cyanosis, pallor, and pulse-feebleness may all arise as the result of laryngeal spasm dependent upon the presence of mucus. Such symptoms indeed may readily be misunderstood and erroneously looked upon as due to the anæsthetic. It is a good plan, therefore, should mucus and saliva be abundantly secreted, to

allow the patient to clear his air-way by coughing and swallowing *before* the operation commences. This particularly applies to cases anæsthetised by the ether-chloroform sequence (p. 417). I have met with one case in which during very deep chloroform anæsthesia the presence of laryngeal mucus appeared to act as the determining factor in bringing breathing to a standstill; and I have been furnished with full notes of another case in which, during a long administration of nitrous oxide and oxygen, breathing ceased in all probability from a similar cause. From all points of view, therefore, it is a good plan, whenever possible, to keep the larynx and trachea free from these secretions; and this can usually be done by properly adjusting the depth of anæsthesia, attending to the posture of the patient (and particularly the position of the head), and sponging out the fauces as occasion may require. Should breathing actually cease, chest compression and systematic artificial respiration must be at once commenced,[1] and the line of treatment followed which has been already discussed when dealing with obstruction from the presence of blood.

Pus.—There is nothing worthy of special notice regarding the presence of pus within the upper air-passages. It may gain access in various ways; and any difficulties connected with its presence must be treated as described above.

Portions of Morbid Growths, Pieces of Necrosed Bone, etc.—These may become dislodged during certain operations within the nose, mouth, naso-pharynx, and larynx, and may possibly obstruct breathing; but there is nothing worthy of special reference concerning the symptoms which would result.

Extracted Teeth, Fragments of Teeth, and Amalgam or other Stoppings.—These are liable, during dental extractions, to fall or fly from the forceps of the operator. Bicuspid teeth are particularly prone to shoot from the forceps whilst being extracted. In most cases no harm results from the escape of such bodies either into the mouth or throat. But there is nevertheless need for the greatest caution during the use of anæsthetics in dental surgery, seeing that several cases

[1] In the *Brit. Med. Journ.*, 18th Nov. 1882, p. 994, a case is reported in which a child of 17 months died under chloroform. At the autopsy large quantities of mucus were found at and below the bifurcation of the trachea.

are on record in which alarming and even fatal symptoms have arisen from the entrance of foreign bodies of this class into the larynx or trachea. The accident seems to have taken place, in most cases, during a deep inspiration. The head of the patient should be arranged as vertically as the nature of the operation and the requirements of the operator may permit; for when the head is thus placed, all substances which may escape from the forceps will tend to gravitate towards the tongue or floor of the mouth, from which situations they may be immediately removed. The head, moreover, should be adjusted so that it is in a line with the body; for if it be extended, the act of swallowing—nature's safeguard against the accidents under consideration—will be difficult or impossible. If a tooth, stump, or fragment should escape into the pharynx, and if it should not be immediately swallowed, it may remain for a considerable time in the epiglottic region, and may ultimately pass into the œsophagus or be forced away by coughing. Shell-like fragments of teeth are more prone than weightier bodies to enter the larynx, owing to their being more easily swept along by the inspiratory current. Should any of the foreign substances under consideration gain access to the larynx or trachea during anæsthesia, some symptoms will, in all probability, occur at the time of entry. Generally speaking, coughing of a spasmodic character is excited; and this may at once dislodge the substance. Sometimes the coughing is so slight as to escape notice. In other cases the foreign body lodges in the larynx and sets up urgent symptoms, such as stridor, cyanosis, and complete cessation of breathing.

In a case reported by Mr. Claremont in 1858 (*Lancet*, 15th May 1858, p. 477), some fragments of teeth entered the larynx during chloroform anæsthesia. When the patient became conscious, after the operation was over, coughing occurred, and a complaint was made of some soreness about the chest. There were, however, at the time, no distinct symptoms of the presence of the fragments. General bronchitis followed. Subsequently the fragments were coughed up from the lungs and the patient made a good recovery.

A case is also mentioned in the *Dublin Med. and Chem. Journ.* for 1834, in which "the root and fangs of a lower molar" entered the right bronchus during extraction. Death supervened in eleven days.

Another case is quoted in the *Edin. Journ.* for 1834, in which an entire lower molar entered the lung. It was coughed up on the eleventh day, and the patient recovered.

In the *Brit. Journ. Dent. Science*, vol. xxii., Jan. 1879, p. 7, a case is related in which a large amalgam stopping shot from a tooth during extraction under nitrous oxide, and presumably entered the larynx. Fortunately the patient coughed it out immediately after the effects of the anæsthetic had passed off.

See also *New York Med. Record*, 4th Nov. 1882, p. 517. Also *Trans. Odont. Soc.* vol. iii., new series, p. 36.

In a case referred to in the *Brit. Med. Journ.*, 18th Feb. 1899, p. 401, an extracted tooth entered the larynx during nitrous oxide anæsthesia, causing extreme cyanosis. Subsequently there was a feeling of tightness in the throat, aggravated by speaking or change of posture. No breath sounds were audible over the left lung. Death took place in twelve days. At the necropsy the tooth was found in the left bronchus.

During the extraction of teeth under anæsthetics the operator should be most careful to leave nothing whatever loose in the mouth. He should remove each tooth or stump as it is extracted, and see that there is nothing hanging to the forceps when that instrument is reintroduced. When several upper roots have to be extracted, the plan of protecting the back of the throat with the corner of a cloth is an excellent one, and should certainly be more widely adopted than it is at present. Although the avoidance of accidents of this kind should rest with the operator, the administrator may often assist the latter. Thus it is possible for the administrator to place a finger across the back of the mouth between the tongue and palate; or to press the tongue against the palate and so shut off the oral cavity from the pharynx.

Should symptoms pointing to the entrance of a foreign body into the larynx manifest themselves, the patient should be bent forwards in the operating-chair, and his behaviour narrowly watched. The spasmodic cough and other symptoms may now quickly subside, the foreign body being either coughed into the mouth, swallowed, or so placed in the air-passages that for a while it sets up very few symptoms. Should coughing, duskiness, and difficulty of breathing continue, the back may be smartly slapped, whilst the patient is bending forwards. Should this not succeed, the patient may be turned on his side with the object of facilitating the exit of the substance. Failing this, inversion should be adopted. This last-named procedure, although open to the objection that it may cause the foreign body to be coughed into the larynx,

where it may induce spasm, has answered in several cases, and should certainly be tried if the symptoms are of sufficient urgency. Should signs of laryngeal spasm (high-pitched stridulous breathing, deep cyanosis, embarrassed and ultimately suspended breathing) supervene, no time should be lost in opening the larynx at the crico-thyroid space, and, if necessary, performing artificial respiration through the opening thus made.

Other Substances.—The other substances on the list, viz. artificial dentures, pivoted teeth, portions of or entire mouth-props or corks, portions of instruments used in laryngeal, dental, or similar operations, pieces of sponge, etc., if by chance they should gain access to or become impacted in the larynx will set up symptoms of an asphyxial character which require very prompt measures. An interesting, though unfortunately fatal case,[1] in which an artificial denture became impacted in the larynx, occurred in 1872, and is well worthy of notice. An unattached mouth-cork has been known to slip from between the teeth and asphyxiate a patient under nitrous oxide.[2] The spring of a Buck's gag has also been known to enter the larynx and eventually lead to a fatal result. These facts should teach us how necessary it is to see that all dental mouth-gags are firmly secured by string or whip-cord; and also that all spring-gags should be avoided in dental surgery (see p. 164).[3] A case has lately been recorded in which a sponge, used in the course of a dental operation, caused the death of a patient by becoming impacted in the upper air-passages.[4]

[1] See *Brit. Med. Journ.* vol. i., 1872, p. 419.

[2] See *Med. and Surg. Reporter*, 1867; and also Agnew's *Prin. and Prac. of Surgery*, vol. iii. p. 44.

[3] A very interesting and instructive case, in which the broken blade of a pair of extraction forceps entered the larynx, is reported by Sir William MacCormac (see *Lancet*, 2nd Jan. 1886). The patient was lying in the semi-recumbent posture on a couch with the head raised by pillows. Chloroform was given. The broken blade entered the larynx during two or three deep inspirations. A violent fit of spasmodic coughing immediately took place. The patient became livid and much distressed. Subsequently dyspnœa, cough. and pain were complained of, and Sir William MacCormac, by a skilfully-planned operation, removed the foreign body, through a tracheal opening, from the right bronchus.

[4] See *Lancet*, 5th Jan. 1901, p. 73.

(*c*) **Obstructive arrest of breathing dependent upon the presence of some direct obstacle to lung expansion.**

We have already studied (p. 42) the respiratory phenomena of anæsthesia, and have seen that, as a general rule, most of the inspiratory work is done by the diaphragm. It is therefore very important that the descent of this muscle should be unimpeded, more particularly when, as is sometimes the case, the thorax would be unable to take on the additional work which would naturally fall to its lot in the event of the diaphragm being unable to act. Similarly, it is important to provide for free thoracic expansion, more particularly in cases in which, for some reason or another, abdominal movements are in abeyance. In more than one of the recorded nitrous oxide fatalities (p. 228) tightly-fitting corsets undoubtedly contributed to the accident. Should the precaution of removing all constricting clothing or bandages have been omitted, and the breathing become embarrassed or cease, no time must be lost in removing all impediments to lung expansion and in performing artificial respiration should this be necessary.

There are certain **postures,** *e.g.* the prone and semi-prone, in which the trunk weight may tell directly upon chest expansion (see p. 138). In such cases small, hard pillows may be advantageously placed under the shoulders and hips in order to allow of the thorax and abdomen expanding as freely as possible. Should breathing become much embarrassed or cease, the patient must at once be placed in the dorsal posture and the ordinary means adopted for restoring breathing.

In certain subjects, and particularly in those who are elderly, obese, and emphysematous, the lithotomy posture may involve a dangerous degree of respiratory embarrassment, and it may be necessary to place the patient in some other position. I have met with one case, for example, in which excision of the rectum had to be performed with the patient in the lateral posture (see p. 140).

Then there are numerous **morbid states** which, whilst they may be compatible with blood oxygenation so long as the patient is conscious, will cease to be thus compatible directly deep anæsthesia has been produced. This may be the case, for

example, in patients with excessive abdominal distension from ascites (see p. 128), or in those with hydrothorax or other pleural or pulmonary diseases. As a general rule, a comparatively light anæsthesia is here indicated, particularly during the period of greatest respiratory distress; and should occasion require, artificial means must be used for maintaining breathing.

The most important condition which is capable of directly preventing lung expansion is **general respiratory spasm.** This spasm, as we have already seen, may either arise (1) during the stage of rigidity and excitement (p. 62); (2) as the reflex result of some surgical procedure (p. 47); or (3) as a sequel to occlusion of the air-tract (p. 448). Minor degrees of respiratory spasm are very common during the induction stage of anæsthesia, but the temporary respiratory embarrassment to which this spasm gives rise usually subsides spontaneously, *i.e.* without treatment. In certain types of subjects, however, complete arrest of breathing may take place, and unless remedial measures be promptly adopted this arrest may persist till the heart fails. It is in this way that strong men die in the early stage of chloroformisation (p. 350). And it is in this way, too, that certain cases are to be explained in which patients have died as the result of an incision during light anæsthesia. The supervention of general respiratory spasm in those cases in which breathing has come to a standstill from some obstruction *within* the air-tract constitutes, as we have seen, a most formidable complication; for even when laryngotomy has been performed for the relief of the obstruction, we may find that we have to reckon with an even greater difficulty, viz. fixity and immobility of the thorax. Lord Lister has described one fatal case of this sort, and it is probable that a large number of others have taken place whose true nature has been overlooked.

For reasons already given, respiratory spasm under nitrous oxide or ether is not nearly so dangerous as under chloroform. The combination of this spasm with the continued absorption of incarcerated chloroform vapour will, in fact, rapidly destroy life; and this is the explanation of that form of syncope which has so often been described as having occurred early in chloro-

formisation. If, at the moment when respiration becomes suspended, there is comparatively little chloroform in the lungs and circulation, the wrist-pulse may remain palpable for a considerable time, the heart holding out against the asphyxial strain with a resistance proportionate to its original vigour. If, however, anæsthesia be deep at the moment breathing ceases, and especially if an overwhelming dose of chloroform has been suddenly given, the strongest heart may become so rapidly poisoned that the respiratory spasm may be attended or immediately followed by pulselessness.

When general respiratory spasm arises and does not spontaneously subside, the mouth should be opened by means of a Mason's gag, the tongue-forceps applied, and artificial respiration by Silvester's method attempted. In the event of these measures failing to restore breathing, it is probably best to at once perform laryngotomy, partly because there may still be laryngeal obstruction present, and partly because, when once a laryngotomy tube has been inserted, it is comparatively easy to apply the treatment which is next indicated, viz. lung inflation. As already explained when dealing with occlusion of the air-tract (p. 448), there are certain exceptional cases in which the chest walls cannot be moved by the usual means even though laryngotomy has been properly performed; and it is in such cases as these that lung inflation holds out the only chance of success. Inversion should not be employed (see p. 479), for such a measure would only increase the distension of the right cardiac cavities. In one case of this class which came under my own observation, simple mouth inflation through the laryngotomy tube started breathing, and undoubtedly saved the patient's life. From the fact that the chest walls would not move even when great pressure was applied to them, it is probable that in this particular case respiration had ceased during the expiratory phase.

Inflation of the lungs, by means of bellows, was the recognised method of performing artificial respiration before the plans now in use were known to the profession. Amongst those who have invented and used specially constructed bellows for lung-inflation may be mentioned John Hunter,[1]

[1] *Asclepiad*, 1890, p. 201 *et seq.*

Sibson,[1] Plouviez,[2] Marcet,[3] Richardson, and Fell.[4] When the simpler and handier methods of Marshall Hall and Silvester began to find favour, inflation of the lungs fell into disuse; and at the present time it is rarely if ever employed. There can be no doubt, however, that under the circumstances above narrated lung inflation is the proper treatment.

Lastly, there are certain **operations about the thorax and abdomen** which may themselves mechanically interfere with breathing. Thus, during the removal of a renal tumour adherent to the diaphragm, complete suspension of breathing may take place each time traction is made. The treatment of such cases, however, hardly falls within the scope of this work.

(B) Paralytic Arrest of Breathing

(*a*) **Paralytic arrest of breathing due chiefly, if not wholly, to an overdose of the anæsthetic.**

The action of anæsthetics upon the nervous mechanism of respiration has been already considered in previous pages; and as special descriptions have been given of the symptoms which characterise an overdose of each agent, it is unnecessary to quote any illustrative cases of this variety of respiratory failure.

In most cases respiratory failure of this kind comes about more or less gradually. The breathing grows shallower and shallower till it ceases altogether; or the standstill is preceded by irregular jerks and inspiratory catches. In very rare cases the arrest takes place with unexpected suddenness. Speaking clinically, non-obstructive cessation of breathing appears to have, as its immediate cause, a sheer inability of the nervous mechanism to carry on respiratory movements. In such cases artificial respiration will be found easy of application, and, if commenced soon enough, remarkably successful.

Shallow and almost imperceptible respiration does not of itself necessarily imply that danger is present. Other signs must be consulted. So long as the normal colour of the face and ears is not materially altered, so long as the pulse is not markedly affected, and so long as the conjunctiva is sensitive

[1] Silvester, *op. cit.*

[2] Kappeler, *op. cit.*

[3] *Proc. Roy. Med. Chir. Soc.* vol. iv., 1861-64, p. 45.

[4] *Brit. Med. Journ.*, 1st March 1890, p. 495; *Brit. Med. Journ.*, 16th August 1890, p. 384.

to touch, feebleness of breathing means very little. For example, it is the rule rather than the exception, after the withdrawal of ether or chloroform, for the respiration to become so tranquil that it can hardly be detected; and the same condition may be met with during the too sparing use of these anæsthetics. Deeper and audible breathing is to be secured by more of the agent in use. But should the feeble respiration coexist with a pallid, dusky, or cyanotic complexion, a small, slow, or irregular pulse, and a totally insensitive conjunctiva, the anæsthetic must be withheld, for these signs collectively indicate that complete cessation of breathing is imminent.

When respiration threatens to come to a standstill, without actually ceasing, and the administrator feels certain that the air-passages are not occluded, the following treatment should be adopted. The anæsthetic should at once be removed, and the lips lightly but briskly rubbed from side to side with a dry cloth. Halting and feeble breathing under chloroform may usually be re-established by lip-rubbing, the immediate effect of which is often very remarkable. I have not unfrequently seen respiration, colour, and pulse immediately improve on briskly rubbing the lips, and it is a measure which should never be neglected in minor cases of difficulty. Sometimes breathing can only be kept satisfactorily proceeding by this little manœuvre. Should these measures not succeed, respiration must be assisted by pressing, with each feeble expiratory movement, upon the chest walls. Gentle rhythmic pressure upon the sternum with one hand, or similar pressure upon the sides of the chest with both hands, may be made. In one or other of these ways actual cessation of breathing may often be averted.

Should the respiration actually cease—and this will be known by the absence of all thoracic and abdominal movements, the increasing duskiness of the face, and inability to feel or hear the passage of air from the mouth or nose—systematic artificial respiration should be resorted to without a moment's delay.

Silvester's Method of Artificial Respiration.[1]—If the patient be lying lengthwise upon a bed, he should be rapidly placed

[1] See *The Discovery of the Physiological Method of Inducing Respiration in Cases of Apparent Death from Drowning, Chloroform, Still-Birth, Noxious Gases, etc.*, by Henry R. Silvester, 1863.

transversely, and his head allowed to hang over the side. Should he be lying upon an operating-table, similar extension of the head may be effected over the end of the table. If he be in the sitting posture at the time of the respiratory failure, he should be at once placed on the ground with his shoulders slightly raised and his head extended. Although

Fig. 58.—Artificial Respiration by Silvester's Method (Expiration). From a photog[raph].

it is here assumed that the air-passages are patent, it is best, as a routine practice, to insert a gag, apply the tongue-forceps, and make traction upon this organ in order to be quite sure that it is not obstructing breathing. As is well known, the respiration may become obstructed so inaudibly that an error in the diagnosis of the kind of respiratory failure may easily be committed. Full extension of the head and neck, as pointed out by Dr. Howard,[1] tends to keep open a free air-way. The

[1] See *Lancet*, 27th October 1888, and *Brit. Med. Journ.*, 7th November 1888, "On Raising the Epiglottis."

administrator should stand behind his patient, and, grasping the arms at the elbows, should press them firmly and steadily against the sides of the chest (Fig. 58). In the vast majority of cases this pressure will cause an expiration; but should it not do so at once, forcible pressure below the costal margins, and directly towards the diaphragm, may be brought to bear.

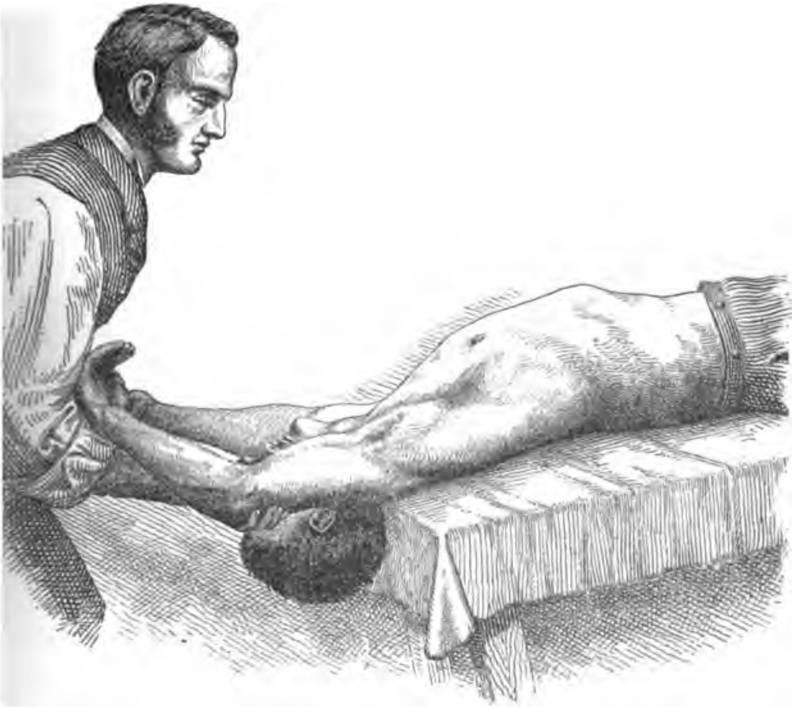


FIG. 59.—Artificial Respiration by Silvester's Method (Inspiration). From a photograph.

After the arms have been steadily pressed against the sides for about a couple of seconds, they should be brought deliberately towards the administrator, so that they come into the long axis of the patient's body, on either side of his head. This procedure usually has the effect of enlarging the capacity of the chest by causing the pectoral muscles to raise the upper ribs. In this way (Fig. 59) inspiration is effected. The arms should be kept extended for about a couple of seconds, after which they may be again brought to the side as in Fig. 58.

These expiratory and inspiratory movements should be repeated regularly and steadily about fifteen times per minute, careful watch being kept for any spontaneous respiration. If any signs of the latter appear, the natural movements should be supplemented by the artificial till the breathing has become thoroughly re-established. Care must be taken throughout to maintain a free air-way, and not to exert undue and unnecessary force during expiration. Ribs have been fractured, and rupture of the liver has actually occurred, from too roughly handling the patient.

In *Pacini's* modification[1] of Silvester's method, the operator, having his abdomen against the head of the patient, places his hands in the dorsal fold of the axillæ, and pulls the shoulders towards him with an upward movement. The shoulders are then relaxed, and the former movement is repeated.

There are other methods of performing artificial respiration; but putting aside those in which the chest is inflated by means of bellows, they are all inferior to Silvester's, in that they do not provide for any inspiratory action beyond that resulting from the elastic recoil which follows chest compression.

Chest Compression.—Rhythmic compression of the chest walls, each compression being followed by a removal of the pressure, has already been alluded to as of service in threatened respiratory arrest. As Sir B. Richardson pointed out,[2] this plan is particularly useful in young subjects, *i.e.* those with elastic thoracic parietes. Indeed, in the treatment of suspended breathing in children, this simple chest compression usually answers as well as any other method of resuscitation.

Marshall Hall's Method.—In Marshall Hall's or the postural method, the weight of the patient's trunk is utilised to effect thoracic compression, *i.e.* expiration. The patient is placed face downwards, his chest being supported by a pillow or folded article of clothing, and he is then gently rolled on to his side. These procedures are repeated about fifteen times a minute. Whilst the patient is lying in the prone position expiration is assisted by making pressure upon the back.

Howard's Method.—For the performance of artificial respiration by

---

[1] Introduced into England by Dr. Bain. See *Lo Sperimentale*, T. xxxvii. 1876, p. 39; *Lancet*, 19th December 1868, p. 799; *Trans. Roy. Med. Chi. Soc.*, 1870, vol. liii. p. 291.

[2] "Artificial Respiration: The Theory and the Practice" (*Asclepiad*, 1890, p. 201).

Howard's method,[1] the patient must be so placed that his shoulders are somewhat raised, and his head and neck fully extended. His hands should be loosely tied together and thrown over his head. The administrator, who must kneel astride his patient, spreads open his hands so that his thumbs and little fingers rest upon the inner margins of the free borders of the costal cartilages, the tips of the thumbs being placed over the xiphoid cartilage. Forcible and sudden pressure is brought to bear upwards and inwards towards the diaphragm for two or three seconds. The pressure is then suddenly removed, the administrator resting for three seconds before repeating the procedure. Seven to ten compressions should be made per minute.

The Administration of Oxygen.—This appears at first sight to be strongly indicated. But Lallemand, Richardson, Perrin, and Duroy[2] have found by experiment that common air answers just as well. The first-named observer, indeed, states that common air is actually preferable. But even if a more extensive trial of oxygen should prove that this gas is preferable to air, the difficulties in the way of keeping it in readiness must always prevent its use save in hospital practice. Dr. Foy[3] speaks strongly in its favour.

Faradism.—Electric stimulation of the phrenic nerves was originally suggested by Duchenne in 1855 as a means of restoring respiration. He found that by the application of the induced current to these nerves he could produce powerful diaphragmatic contraction in lower animals; and that a similar result could be obtained in the human subject some considerable time after death. He ascertained, moreover, that in animals poisoned by chloroform, the electrical excitability of the phrenic nerves remained almost or wholly unaltered.[4] Duchenne advised that each electrode of an induction apparatus should be placed over the lower end of the scalenus anticus muscle, on the outer edge of the sterno-mastoid. The latter muscle should be drawn somewhat inwards. The electrodes having been placed in position, the current was turned on for about a couple of seconds, when the diaphragm was found to contract and an audible inspiration to result. Expiration was assisted by compressing the lower part of the thorax and the abdomen for a couple of seconds. The faradisation of the phrenics was then repeated. By employing somewhat larger electrodes than those at first used, Duchenne found that he was able to call into action other muscles capable of assisting inspiration, such as the sterno-mastoid, trapezius, levator anguli scapulæ, the pectorales, the serratus magnus, and the rhomboidei. Faradisation of the phrenics was used successfully by Ziemssen[5] in 1856, in a case of asphyxia; and the same author has recorded a similarly happy result in a case of chloroform poisoning. In the latter case the current seems to have been applied directly to the diaphragm. Snow[6] relates a case in which a "galvanic apparatus," which happened to be in

[1] *Brit. Med. Journ.*, 16th August 1890, p. 384.
[2] Kappeler, *op. cit.* [3] *Brit. Med. Journ.*, 23rd January 1892.
[4] See *De l'Électrisation localisée*, by Duchenne, 1872.
[5] See Kappeler, *op. cit.* p. 131.
[6] *Op. cit.* The current employed was probably an interrupted (faradic) one

readiness, proved very successful in effecting inspiration in a patient who had ceased to breathe during chloroform narcosis; and in this case also the electrodes were applied to the diaphragmatic region and not to the phrenic nerves.[1] In the fatal cases collected by Snow mention is made of "galvanism" on several occasions. The effects, however, do not appear to have been very marked. When readier methods of artificial respiration became known, faradism gradually commenced to fall into disuse. At the present time it is rarely if ever employed, principally for the reason just mentioned, but partly also because of the difficulties in the way of always having at hand an induction apparatus in working order. It is questionable, however, whether faradism should be completely discarded. When an entry and exit of air can be brought about by Silvester's method, any attempt to carry on artificial respiration by electrical stimulation either of the phrenic nerves or of the diaphragm itself must be regarded as out of place. But should the chest be rigidly fixed, so that all manual methods of artificial respiration prove fruitless, and should an induction apparatus be at hand, faradism of the phrenic nerves should certainly be tried. We have yet to learn whether this immobility of the chest walls—one of the most alarming complications of anæsthesia, and one to which reference has already been frequently made—is the result of spasm of the expiratory muscles. If future observation should lead to this conclusion, faradism may yet be destined to save many lives.

Experience leads me to believe that drugs are of little or no value in the treatment of this form of respiratory failure. With regard to prognosis we may say that, if a pulse can be detected at the wrist when respiration ceases, and air can be made to enter and leave the chest, recovery may almost certainly be looked for. But even though the pulse cannot be felt, the administrator should by no means despair, but promptly commence and perseveringly continue artificial respiration. It is almost unnecessary to say that artificial respiration must be kept up so long as there is the slightest chance of restoring the patient. Recovery has been known to take place some considerable time after all signs of natural

[1] Dr. H. Lewis Jones, who is in charge of the Electrical Department at St. Bartholomew's Hospital, has kindly compared for me the effects produced by faradisation of the phrenics and faradisation in the region of the diaphragm. He finds by experimenting upon himself and upon me that the application of the electrodes over the phrenics, as suggested by Duchenne, produces very distinct diaphragmatic contraction with immediate entry of air to the lungs, whilst the application of the current to the diaphragmatic region produces violent expiratory efforts apparently from the contraction of the intercostal and abdominal muscles. The application of the current to the phrenic nerves in the neck is not always an easy matter; but when once the nerves have been found (and it is easy to tell when this has been accomplished by the effects produced), the inspiratory action of the diaphragm is very striking.

respiration and circulation have been in abeyance.[1] The most formidable cases are those in which respiration and circulation almost simultaneously cease (p. 355).

(*b*) **Paralytic arrest of breathing due chiefly, if not wholly, to other causes than an overdose of the anæsthetic.**

Paralytic respiratory failure during anæsthesia is undoubtedly sometimes due, either wholly or in part, to **cerebral anæmia.** Leonard Hill has particularly insisted upon this fact (p. 82), and I can corroborate his views from a clinical standpoint. In the case of ether the administration of an overdose leads, as we have seen, to a paralytic cessation of breathing which is not, as a rule, dependent in any way upon cerebral anæmia; but in chloroform toxæmia the arterial tension is often so reduced that the blood supply to the respiratory centre is more or less suspended, and the breathing fails as much from the general fall of tension as from the chloroform-laden blood. Cases of chloroform syncope have been recorded in which the breathing reappeared and disappeared as the trunk was alternately inverted and brought to the horizontal plane. Other things being equal, patients in the vertical posture are more liable than others to display indications of anæmic arrest of breathing.

But in addition to the anæsthetic itself directly or indirectly reducing arterial tension and so leading to this variety of respiratory failure, there are other factors which, as we shall see in the following chapter, may bring about such a fall of tension that this anæmic arrest of breathing takes place. Thus, in surgical shock, whether produced by hæmorrhage or by interference with important structures (see p. 142), the breathing is invariably shallow, and in the most profound shock it may cease altogether (see Illustrative Case, No. 45, p. 484).

Again, in cases in which **morphine** has been given there is

[1] I have myself known automatic breathing to return after four hours' artificial respiration. (See Illust. Case, No. 30, p. 425.) In the *Edin. Med. Journ.*, November 1874, a case of chloroform poisoning is recorded in which recovery followed after two and a half hours of artificial respiration. In these protracted cases evidences of cardiac activity were to be detected although natural respiration was in abeyance.

a greater liability than usual to paralytic suspension of breathing (see p. 425).

And lastly, I have notes of one or two interesting cases in which breathing has apparently ceased from what may be termed **reflex respiratory inhibition.** The following case will illustrate this point:—

Illustrative Case, No. 39.—M., æt. 51. ? A malingerer. Abdominal incision. Ether. Clover's inhaler for induction, then Ormsby's. Well under. Abdomen relaxed. No corneal reflex. Respiration deep and stertorous. Then less full. Good colour. Sudden cessation of breathing at moment of incision. Recommenced very feebly and with long pauses. For the first half-minute of feeble breathing colour good, but soon became dusky. Chest compression soon restored respiration.

In another case of which I have notes, breathing also suddenly ceased at the moment of an abdominal incision during deep anæsthesia, but as there was some rigidity of the abdomen and chest, the case may possibly have been one of reflex respiratory *spasm* rather than inhibition.

In treating cases belonging to this category it is, as a rule, advisable to combine partial or complete inversion of the body with artificial respiration. The former procedure, as we shall see below (p. 479), increases the cerebral blood supply; the latter eliminates the anæsthetic and acts as a powerful cardiac stimulant. The usual precautions as to keeping the air-way free (p. 466) must, of course, be borne in mind. With regard to other remedial measures these must be looked upon as of secondary importance; but should opportunities be favourable, the drugs recommended for the treatment of circulatory failure (p. 482) may be employed whilst artificial respiration is proceeding. Of these strychnine is most likely to be of service, and may be subcutaneously given in doses of about $\frac{1}{40}$th gr.[1]

[1] Dr. H. C. Wood has kindly sent me a pamphlet entitled ***Strychnine as a Respiratory Stimulant***, which gives his experiments with this drug. In one case of opium poisoning, seven injections, each of $\frac{1}{16}$th gr. of sulphate of strychnine (=about 6 min. of Liq. Strychninæ Hydrochloratis) were given. See also a case of chloroform poisoning (2 oz. swallowed) in which strychnine was apparently of use (*Brit. Med. Journ.*, 20th November 1897, p. 1498).

CHAPTER XVIII

THE MANAGEMENT AND TREATMENT OF THE DIFFICULTIES, ACCIDENTS, AND DANGERS CONNECTED WITH CIRCULATION

BEFORE discussing the treatment of threatened or complete arrest of the circulation during the state of surgical anæsthesia, it is necessary to clear the ground by a few introductory remarks.

It may, in the first place, be stated that disturbances of the peripheral circulation are exceedingly common during anæsthesia, and that in a considerable proportion of the cases in which such disturbances are noted there is no necessity for anxiety on the part of the anæsthetist. It by no means follows, because the pulse has ceased at the wrist, that the heart has ceased also. Just as many of the respiratory phenomena displayed by anæsthetised patients may be misinterpreted, so may many of the circulatory phenomena be misunderstood and ascribed to causes which are not at the moment in operation. There is, perhaps, a greater liability for errors of this kind to creep in when studying the pulse than when observing the respiration; and this probably explains the existence of a doctrine which is unfortunately prevalent in many quarters, viz. that the pulse should be wholly disregarded during the administration of anæsthetics. It is urged by those from whom this doctrine emanates that any attention to the pulse may interfere with the vigilant observation of the breathing, and that, in addition to this objection, pulse-changes may actually mislead. I cannot too strongly dissent from such teaching. As will be presently seen, there are many cases in surgical practice in which

pulse-indications are of the greatest possible value; and the anæsthetist who ignores these indications is closing the door of knowledge in his own face. It is not a difficult matter for a man of average ability to occasionally feel the pulse without relaxing his attention to the breathing. Moreover, should pulse-indications mislead (as they unquestionably may), it is because the anæsthetist is in ignorance of the true causes of the circulatory changes which are taking place before him. Provided there be nothing in the general state of the patient to depress the circulation; that the anæsthetic be administered only to a *moderate* degree—in other words, without completely abolishing the corneal reflex; and that respiration be freely performed, pulse indications will certainly be of little or no value. But in modern surgical practice we often have to anæsthetise patients whose circulation, either from some pre-existing cause or from intercurrent surgical shock, is in a very unsatisfactory state; and we frequently have, moreover, to administer an anæsthetic to such a degree that no trace of corneal reflex is present; and it is under one or other of these circumstances that the pulse will very greatly assist us. To take the peripheral circulation as the sole or even the principal guide in the administration of an anæsthetic would be the worst possible practice; but to study its changes from time to time is, I believe, essential if we wish to obtain the best results.

There are numerous causes upon which circulatory depression or failure during anæsthesia may depend. They are as follows:—

A. Predisposing Causes.

(i.) Any general impairment of health, such as that dependent upon anæmia, jaundice, renal disease, shock from injury or loss of blood, etc.; and particularly any grave respiratory or cardiac affection;
(ii.) Profound mental disturbance;
(iii.) The sitting posture; and
(iv.) The presence of food or fluid within the stomach.

B. Exciting Causes.

(i.) Embarrassed or arrested breathing;
(ii.) The effects of the anæsthetic itself upon the cardio-vascular system;
(iii.) The surgical procedure; and
(iv.) The act of vomiting.

It will now be convenient to discuss these predisposing and exciting causes *seriatim.*

A. PREDISPOSING CAUSES OF CIRCULATORY DEPRESSION OR FAILURE

(i.) **Any General Impairment of Health, such as that dependent upon Anæmia, Jaundice, Renal Disease, Shock from Injury or Loss of Blood, etc.; and particularly any grave Respiratory or Cardiac Affection.**—The influences of the various morbid states which may be present in patients about to be anæsthetised have already been considered (p. 114 *et seq.*). Other things being equal, it is obvious that the more vigorous the circulation the longer will it be able to withstand any given strain (asphyxial or otherwise) to which it may be subjected. In the case of anæmic, cachectic, and wasted subjects, comparatively small quantities of chloroform may bring about circulatory and respiratory depression; but owing to the fact that in such patients artificial respiration is usually easy of performance, recovery may generally be anticipated, provided this all-important remedial measure be promptly applied. We have already seen that patients with fatty, flabby hearts and rigid chest walls are more liable than others to fatal syncope during the struggling stage under chloroform, the explanation being that in such cases it is often difficult to effect an entry of air to the lungs before the heart has become paralysed. And we have also seen that, even though ether be chosen for anæsthetising patients whose general state is at the time exceedingly unsatisfactory, death may arise from cardiac syncope during some slight respiratory embarrassment. Moreover, there are certain special morbid states which may on very rare occasions lead to fatal circulatory failure during anæsthesia. Thus, during the administration of an anæsthetic to a patient suffering from venous thrombosis, a thrombus may become dislodged and (as in the following interesting case) arrest cardiac action.

Illustrative Case, No. 40.—F., æt. 32. Wasted. Nervous. Heart-sounds rather feeble. No heart or lung disease discoverable. There had been œdema of left leg. Operation for removal of large fungating

sarcoma of right breast. Ether by Clover's inhaler. Anæsthetic taken well. No cough, struggling, or cyanosis. Good pulse. Corneal reflex had just disappeared when operation begun. No reflex movement on incision. Growth removed in about three minutes. Pulse suddenly became feeble and face pale. Very little bleeding at site of operation. Pulse ceased. Respiration continued for some minutes. Operation at once stopped (15-20 minutes after commencement of administration, and every means tried to restore patient (artificial respiration, strychnine, etc.), but without success. *Post-mortem*: Rigor mortis marked. Much wasting. Pleuræ: *nil.* Lung emphysematous: not gorged with blood: no bronchitis. Heart weighed 8 oz.: left ventricle firmly contracted and empty: right ventricle moderately contracted and containing 1 oz. of fluid blood. In right side of heart, entangled in tricuspid valve, is an ante-mortem clot, consisting of a thick portion 1 inch long, ½ inch in diameter, and irregularly cylindrical, with three longer thinner portions from ⅓ to ¼ inch in diameter, and 2 to 4 inches long (clearly formed in some vein). Pulmonary, tricuspid, and aortic valves normal. Mitral also. Partial thrombosis of left common iliac vein. Nothing else abnormal.[1]

(ii.) **Profound Mental Disturbance.**—The effects of fear and profound mental disturbance upon the circulation have been discussed on p. 344.

(iii.) **The Sitting Posture.**—The influence of this posture has already been fully considered (p. 141). In actual practice this influence may be disregarded in the case of nitrous oxide and of ether, provided that the circulation be not depressed by any of the other conditions under consideration. Should signs of syncope manifest themselves when a patient is in the sitting posture, it is advisable to place him horizontally. With chloroform it is best, as a general rule, to avoid the sitting posture as far as possible, for, should syncope from one or other of the causes under discussion manifest itself, the vertical posture would tend to aggravate the condition. There seems to be very little evidence that the sitting position is of *itself* a danger in chloroformisation, provided that the respiration be unembarrassed and the corneal reflex not completely abolished.

(iv.) **The Presence of Food or Fluid within the Stomach.**—As already explained (p. 349), an eccentric form of anæsthesia may be met with when undigested food or drink is present in the stomach. I have notes of many cases of this

[1] For the above notes I am indebted to Dr. Schorstein and Mr. E. E. Prest. It is entirely owing to Dr. Schorstein that the true cause of death was discovered; and Mr. Prest's notes of the administration render the case complete.

kind in which the pulse, colour, and respiration have remained unsatisfactory throughout the administration.

B. EXCITING CAUSES OF CIRCULATORY DEPRESSION OR FAILURE

(i.) **Embarrassed or Arrested Breathing.**—This is an exceedingly common cause of pulse-failure during anæsthesia. There is good reason, indeed, to believe that in a very large number of the cases in which the first symptoms of danger observed have been disappearance of pulse and change of colour, some initial embarrassment to breathing has been overlooked. For example: a child is operated upon for the removal of post-nasal adenoid growths: the operation is successfully finished: the patient, who is beginning to "come round," is moved back to bed and placed horizontally: the breathing becomes suspended by reason of commencing vomiting (laryngeal closure), and possibly the presence of coagulated blood about the rima glottidis: cyanosis ensues: then pallor: then pulse-failure: and, unless the patient's condition be observed in time, death quickly takes place. Unless the surgeon is aware of the liability of such patients to pass into this condition of asphyxial syncope, he may overlook the asphyxial factor. It has been pointed out in preceding parts of this work that respiration is exceedingly liable to become temporarily embarrassed during anæsthesia; and the rapidity with which the peripheral circulation will cease will depend upon the normal state of the patient's vascular system, the particular anæsthetic employed, the degree of anæsthesia, and other factors.

The treatment of all states of circulatory depression dependent upon impaired or suspended breathing is sufficiently obvious. It is to correct any respiratory embarrassment, and, if necessary, to perform artificial respiration in the manner fully described in the preceding chapter.

The following case may be of interest as illustrating this form of circulatory failure and the proper treatment to be followed:—

Illustrative Case, No. 41.—A thin, middle-aged man, with spinal disease. Heart displaced by distorted spine. Apex beat in fourth space

outside nipple. Marked pulsation in second left space close to sternum. Blowing systolic bruit at base. No thoracic movement. Respiration wholly diaphragmatic. Laminectomy. Left lateral posture. Ether administered by Clover's inhaler. Student administering under my supervision. No excitement. Breathing rather short and colour rather dusky. Patient now placed almost prone with trunk somewhat raised. Operation begun. Very little bleeding. Breathing jerky: colour dusky: pulse bad. No ether given for about 10 minutes (rather more than necessary had been administered). Pulse, however, grew worse, becoming very rapid and irregular. It then ceased at wrist. Respiration continuing. Colour pale and dusky. Hands cold and blue. At this point I was obliged to ask the surgeon to alter the patient's posture. He was accordingly turned to one side, and improvement immediately commenced. The colour of face and lips now returned, *but hands remained very blue*, showing that cyanosis is not necessarily an indication that the heart is satisfactorily pumping along non-oxygenated blood. The improvement continued and the operation was completed.

In the above case the embarrassed breathing (from pre-existing intercostal paralysis and the prone posture) gradually led to pulselessness. Possibly the cardiac condition (the nature of which I was unable to diagnose), together with the displacement of the heart, contributed to the pulse failure.

(ii.) **The Effects of the Anæsthetic itself upon the Cardio-vascular System.**—We have seen that when nitrous oxide or ether is administered in toxic doses to a moderately healthy subject some impairment of breathing invariably precedes pulse-failure; whereas in the case of chloroform a variable degree of circulatory depression is a common and conspicuous accompaniment, if not a precursor of respiratory arrest. When anæsthetising patients, however, whose general condition is highly unsatisfactory, the administration of toxic quantities of any anæsthetic, whether it be nitrous oxide, ether, or chloroform, may be attended by more or less sudden and primary cessation of pulse.

The first treatment to be adopted in all such conditions is to withdraw the anæsthetic, to place the patient horizontally (unless he be already so placed), and to increase respiratory action. Many a life has been sacrificed by erroneously resorting to drugs. In comparatively minor cases in which the pulse has become very slow, feeble, irregular, or intermittent, whilst respiration is still continuing, all that is needed, as a rule, is to rub the lips briskly and assist the feeble respiratory

efforts by chest compression.[1] These measures will often ward off a more alarming state, the pulse and colour quickly improving in response to this simple treatment.

But in most cases primary pulse-disappearance from the toxic effects of an anæsthetic is such a grave symptom that vigorous measures are at once needed, and it is advisable to insert a Mason's gag, apply the tongue-forceps, extend the head over the end of the table, and proceed to Silvester's method of artificial respiration as already described. The gag and tongue-forceps are needed to maintain a free air-way; the lowering of the head is likely to be of use in keeping up the blood supply to the respiratory centre; and artificial respiration is the best cardiac stimulant.

Should there be no respiratory embarrassment or evidences of general venous engorgement, partial or complete inversion, as originally suggested by Nélaton in 1861, may be advantageously combined with artificial respiration. Many remarkable cases are on record[2] in which patients have thus been rescued from imminent death during chloroform anæsthesia. The beneficial effects of inversion are probably due, partly to an increased quantity of blood reaching the right heart, partly to a similar increase in the cerebral blood supply, and partly perhaps to the pressure brought to bear upon the feebly acting heart by the abdominal viscera. In some of the recorded cases in which Nélaton's method has proved successful, the pulse at the wrist could be made to come and go as the patient was inverted or placed horizontally. In children, inversion is easily enough applied; but in adults there is necessarily greater difficulty. It is sometimes a good plan, in heavily-built subjects, to secure the feet to the end of the table or bed, and to raise that end. It is important that this treatment should be restricted to the proper cases. It should never be employed unless the signs of primary circulatory failure are distinctly marked.

In the event of these measures failing to resuscitate the

[1] These cases must be carefully distinguished from those in which pulse-feebleness is connected with a *light* anæsthesia or with surgical shock.

[2] See *Deutsche med. Zeitung*, Feb. 1885; *Braithwaite's Retrospect*, vol. i., 1876, p. 348; *Edin. Med. Journ.* vol. ii., 1874, p. 476. Kappeler states (p. 135) that Schuppert saved three patients by inversion.

patient, an attempt should be made to stimulate the heart by direct compression. In the case of young subjects in whom the chest walls are resilient there is no great difficulty in applying intermittent pressure, as in the case referred to on p. 489. In older subjects forcible pressure may be made in an upward and backward direction from below the costal margin.

Drugs are of little if any service in cases of this class, and if employed *should be administered, not by the anæsthetist, but by some other person present.* The anæsthetist's undivided attention must be devoted to maintaining *efficient* artificial respiration and a proper posture. To commence the treatment of a marked case of chloroform syncope by a hypodermic injection of ether or brandy is not only useless (seeing that the circulation is more or less suspended), but dangerous, in that such a procedure delays the application of artificial respiration, the remedial measure by which the elimination of the anæsthetic and the aëration of the blood are effected, and the measure of all others which is most likely to increase cardiac action. There is, of course, no objection to the employment, by some other person than the anæsthetist, of such drugs as ammonia,[1] nitrite of amyl,[2] strychnine, or caffeine[3]; but these substances should only be used as adjuncts, and in the manner described.

It is doubtful whether faradism is of any value as a remedial measure in these cases. Professor MacWilliam[4] advises rather strong induction shocks, with the skin moistened, one electrode being placed over the heart's apex, and one over the fourth dorsal vertebra. Schäfer and Sigmund Meyer, on the other hand, consider faradism to be as likely to inhibit as to stimulate a feebly acting heart.

The worst and most fatal cases are those in which an

[1] Ringer found that ammonia restored the action of a frog's heart which had been arrested by chloroform. See *Practitioner*, vol. xxvi., 1881, p. 436. Pickering, in his experiments with the embryonic heart of a chick, also found that he could partially restore cardiac rhythm by means of ammonia.

[2] Dr. Wood's experiments with this drug lead him to regard it, at all events in chloroform-syncope, as valueless.

[3] This may be given subcutaneously in 2 gr. doses.

[4] "Electric Stimulation of the Heart in Man" (*Brit. Med. Journ.*, 16th Feb. 1889).

overwhelming dose of chloroform has been given during or immediately after violent struggling. Although it is true that in cases of this kind some degree of respiratory embarrassment occurs, the prominent and appalling symptom is pallor and complete cessation of pulse. Our resources on these occasions are unfortunately very inadequate; for beyond the treatment already considered we know of no other restorative measures likely to be of service.

(iii.) **The Surgical Procedure.**—In general surgical practice the operation is itself a common cause of circulatory depression or failure during anæsthesia, and, as we have already seen (p. 142), all varieties and grades of surgical shock may be met with. The treatment to be adopted may be discussed under two heads—preventive and immediate. In those cases in which the surgical procedure is likely to prejudicially affect the circulation, special precautionary measures should be adopted, particularly when dealing with feeble subjects. Violent purgation should be avoided; the room kept warm; the bodily heat maintained by woollen clothing, and, if necessary, a hot-water bed; the surface of the body exposed as little as possible, and all undue delay both in anæsthetisation and in operation avoided. In very feeble subjects an enema of beef-tea and brandy may be given half an hour before the operation. A careful attention to posture is also advisable (see p. 138). As regards the best anæsthetic to be employed, it must be remembered that, whilst there is distinct evidence that, other things being equal, surgical shock is more common under chloroform than under ether, the amount of blood lost, in any given operation, is certainly greater under ether than under chloroform. Then again, some surgeons go so far as to maintain that ether masks surgical shock whilst chloroform allows it to be seen in its true light, and that hence the latter is preferable to the former anæsthetic in the cases we are now discussing. The selection of the anæsthetic should depend, however, upon more important considerations (p. 105). As regards the depth of anæsthesia to be maintained when signs of surgical shock appear, the general rule may be laid down—the greater the shock the lighter should be the anæsthesia. The first step, indeed, in the immediate

treatment of surgical shock is to lessen or altogether withdraw the anæsthetic. In cases in which hæmorrhage has been free, numerous important structures have been divided, and large cutaneous or cut surfaces exposed for a considerable time, the question often arises, how long the operation should be allowed to continue. I have usually found that so long as the pulse can be counted at the wrist, so long may the patient be kept upon the operating-table. I am speaking of those cases in which signs of exhaustion from loss of blood and general shock come on gradually. Should the pulse become a running pulse, or almost imperceptible, no time should be lost in removing the patient to bed.

When the shock is due to hæmorrhage the head and shoulders should be lowered, the legs raised, an enema of hot water and brandy or hot coffee and brandy given, and in desperate cases normal saline fluid injected into a vein.

In minor cases of simple reflex cardiac inhibition it is as a rule advisable, if the patient be deeply anæsthetised, to lessen the degree of anæsthesia, and if chloroform has been in use, to sprinkle a little ether on the mask, or to change to a chloroform and ether mixture or to ether itself. In more pronounced cases a stimulant enema may be given, and a subcutaneous injection of strychnine ($\frac{1}{40}$th grain) or caffeine (2 grains) employed. Partial inversion, the intravenous injection of saline fluid, and artificial respiration may be needed in the worst cases. Although I have seen several alarming cases of this kind, I have never witnessed a fatality (see p. 144). Other forms of surgical shock, whatever their immediate causation may be, are to be treated upon similar lines. It is in cases of this category that drugs are distinctly of service, but the withdrawal of the anæsthetic, partial inversion, the application of warmth, and, above all, the introduction of saline fluid into the veins, are the cardinal remedies upon which reliance may be placed.

The two following cases illustrate the effects of very profuse hæmorrhage upon the circulation of the anæsthetised patient. In Case 42 the patient was at the time of operation considerably depressed by purgation, and this may have had some influence in the causation of the symptoms. In Case 43 the

patient was a thin, feeble woman, and unable to bear loss of blood without quickly showing signs of exhaustion. By anticipating shock, it was possible to tide her over a somewhat formidable operation. Towards the close of the operation I was able to maintain an analgesic rather than a truly anæsthetic state.

Illustrative Case, No. 42.—F., æt. 60. Rather stout; not very strong. Fair chest expansion. Heart-sounds rather distant. No winter cough. Had one ounce of castor-oil the night before operation. Three actions of bowels. Operation 8.30 A.M. for removal of left upper jaw for sarcomatous growth. "Gas and ether" given. Deep ether anæsthesia soon came on. Operation commenced after five minutes of ether anæsthesia (see p. 147). The "gas and ether" had been given by Mr. Braine's method (see p. 404). Head on side, with right cheek on pillow, and face turned towards floor. Operation begun. No embarrassment to breathing from blood, as all drained into, and then out of, right cheek. As effects of ether passed off, anæsthesia kept up by chloroform from a Skinner's mask. Very profuse hæmorrhage. Less anæsthetic given. Respiration quite regular. Pulse not observed. Head always kept low. Conjunctival reflex just present. As the hæmorrhage continued to be free I attempted to feel pulse, but could not detect one at either wrist. Hands quite warm. Respiration proceeding regularly. Lion forceps now applied and jaw removed. Very little hæmorrhage, probably from feeble circulation. Sutures rapidly inserted, and operation finished. Respiration still regular, but occasionally feeble. Still no pulse. Half an ounce of brandy, with some water, given per rectum; a subcutaneous injection of ether administered, and ammonia applied to nostrils. No effect produced. Respiration could be kept proceeding satisfactorily so long as the lips were occasionally briskly rubbed with a towel (see p. 465). Lips pale, but pinkish. Ears and cheeks pale. The wrist-pulse remained absent for 20 or 25 minutes, and then gradually returned. Head kept low. Hot cloths applied to head. Even when the patient became half-conscious, the wrist-pulse was barely perceptible. The patient made an excellent recovery.

Illustrative Case, No. 43.—F., æt. 40. Short stature and thin. Large cystic sarcoma of left breast. The tumour rendered a stethoscopic examination of heart almost impossible. Operation for removal of growth. Ether given by means of Clover's portable inhaler. Pulse during first part of operation very fair. Tumour very vascular: hæmorrhage free. Pulse gradually grew weaker and quicker. The first indications of shock were: (1) quickened pulse; (2) dilatation of pupil; and (3) some pallor. Although the patient was well under the anæsthetic when incisions made and removal of breast begun, she was allowed to regain lid-reflex when the hæmorrhage became free. For the last 20 minutes of operation she was more or less conscious, with widely-dilated pupils, good conjunctival reflex, weak and rapid

pulse (about 130), and considerable pallor. A breath of ether with plenty of air given occasionally. Respiration quiet, shallow, and regular. Whilst sutures were being put in she was able to answer questions, though feebly and slowly. The operation lasted one hour. It may be added that any attempt to keep up a deeper anæsthesia than that described was at once followed by greater rapidity of pulse and loss of tone in the eyelids, so that a moderately deep anæsthesia was maintained after the skin incisions had been made and the removal of the tumour begun.

In one case of profuse hæmorrhage of which I have notes I observed that the wrist-pulse was only palpable during *expiration*.

That the surgical procedure may, independently of the occurrence of hæmorrhage, very seriously and sometimes very suddenly depress the circulation of the patient, will be seen from the remaining illustrative cases.

Illustrative Case, No. 44.—Healthy-looking child, about 5 years of age. Nephrectomy for sarcoma of kidney. Chloroform on Skinner's mask administered by a student under my supervision. All went well till 15 minutes after the commencement of the operation, when, during the manipulations of the surgeon, the following events occurred in the order mentioned:—(1) The pulse became very slow, the respiration being regular and the colour good. The anæsthetic was withheld. (2) The pulse became slower and feebler, and the respiration almost imperceptible, whilst the lips remained of good colour. (3) The radial pulse ceased and the colour became dusky. Inversion and artificial respiration very quickly restored the circulation.

Illustrative Case, No. 45.—F., æt. about 35. Very anæmic from long-standing hæmaturia. Short stature and spare build. Pulse 84, regular and extremely compressible. No respiratory difficulty. Nephrectomy for renal tumour. Time 10.40 A.M. Administration commenced with A.C.E. mixture on Skinner's mask. At 10.42 respiration rather rapid—suggestive of hysteria. 10.43, Ormsby's inhaler, charged with ether, gradually applied. Deep anæsthesia rapidly produced. Pulse fair, but quicker than before commencement. Patient lying on side with pillow under loins: head low: face towards bed. Respiration regular and not hampered. 10.52, operation begun. No reflex movement. At 11, whilst pedicle was being tied, distinct evidences of shock began to manifest themselves. Pulse rapid and feeble. Allowed patient to regain conjunctival reflex to a slight extent. Respiration regular and snoring. Pulse soon became barely perceptible at wrist. Hands warm. Fair colour. Respiration less deep and non-stertorous. As pulse now almost imperceptible, operation rapidly completed. Whilst the patient was in this condition the breathing was suddenly "held" as if straining or coughing were imminent; but as the suspended respira-

tion persisted, the sternum was pressed five or six times, and air was heard to enter and leave the chest. Automatic breathing then returned and continued, though with occasional pauses. End of table raised. Operation completed. Patient's condition gradually improved. Fifteen minutes after operation the pulse could be counted at wrist. Patient moved to bed and kept very warm. No vomiting. Made a good recovery.

Nephrectomy in a feeble and very anæmic patient is prone to be attended by shock, and, as the above case shows, the resources of the administrator may be severely taxed. That the symptoms were not due to loss of blood is perfectly certain, seeing that every care was taken, and with the most perfect success, to avoid unnecessary hæmorrhage. Nor was the anæsthetic to blame, for the symptoms in no way corresponded with those dependent upon an overdose of ether. I have notes of several other cases of nephrectomy in which profound surgical shock (coming on independently of hæmorrhage) has occurred. In one instance yawning was a prominent symptom and the wrist-pulse vanished. The patient, however, made a good recovery.

Extensive operations upon the breast are, as already pointed out, very liable to be attended by surgical shock, and such symptoms may arise independently of hæmorrhage. The following case may be regarded as more or less typical:—

Illustrative Case, No. 46.—F., about 65. Stout. Average height. Large abdomen and fat chest-walls. Good heart sounds. No cough. Has enjoyed good health. Operation: removal of right breast and axillary glands. Administration lasted 40 minutes. A.C.E. given, first on Skinner's, then on Rendle's mask. No difficulty. Then ether on Ormsby's inhaler. Operation begun. No reflex movement. Long incision. Full pulse. Ether caused slight cough and embarrassment to breathing, so changed after a few minutes to A.C.E. After 10-12 minutes, patient being just properly under, with very slight conjunctival reflex, it was difficult to feel pulse either at temporal or superior coronary. Breathing good. Radial pulse slow and barely perceptible. Ether again given and pulse distinctly improved. Ether used for rest of operation. The axilla was being opened up when the symptoms of shock arose.

Although reflex shock in breast operations is more common and more pronounced under chloroform and its mixtures than under ether, it may undoubtedly arise under the last-named agent, as the following case shows:—

Illustrative Case, No. 47.—F., æt. 70. Active. Stout. Good regular heart-sounds. No evidence of bronchitis. No breathlessness. Amputation of left breast. 9.30 A.M. No food or drink since last night. Administration conducted as described on p. 415. A.C.E. mixture given on Skinner's mask. No resistance or difficulty. Changed to Rendle's mask in a minute or two. Breathing rather quick. Then changed to Ormsby's inhaler charged with pure ether. No difficulty beyond transient "holding of breath." No struggling. Soon stertorous, but with slight conjunctival reflex. As the breathing was rather jerky (from large abdomen) and the lips flapped audibly with expiration, somewhat less ether was given. Breathing less jerky. Two very long skin incisions made. No movement or reflex noise, but a slight hesitation in breathing noticed, *i.e.* a slight straining with expiration. As the anæsthetic was continued this quickly passed off and breathing became regular. Although colour and respiration good, no pulse could be detected either in radial or temporal artery. The colour was perhaps a trifle paler than normal, but nothing more. Pupils moderately contracted. Very slight lid-reflex. Ether suspended for a while. Still no pulse: but respiration proceeding. After pulse had thus been absent for about 10 minutes, it returned, and with it brisk lid-reflex and some expiratory phonation. For rest of operation pulse good and regular, and colour very good. Administration lasted one hour. 4½ oz. of Robbins's ether used. Some retching after.

There is an interesting point in connection with breast operations, viz. that directly the suturing of the wound begins, the circulation generally commences to improve. A similar improvement in pulse is observed in abdominal surgery.

In the following case reflex cardiac inhibition took place as the result of the skin incision for a Syme's amputation, the patient being at the time lightly under ether:—

Illustrative Case, No. 48.—M., æt. about 18. Thin: breathless on slight exertion: has some dulness at bases of lungs. Syme's amputation for sarcoma of foot. Commenced administration with a small quantity of the A.C.E. mixture on Skinner's mask. Then went on with pure ether from a Clover's portable inhaler. He breathed the ether well at first; but soon commenced to give some trouble. The upper lids became raised, and it was difficult to secure tranquil anæsthesia. The lid-reflex persisted, and also some muscular movements, for about 10 minutes. Breathing somewhat hampered. Whilst he was in this condition the operation was commenced. It so happened that I had my finger upon the radial pulse, and that the student who was administering the ether under my supervision had his finger upon the carotid artery. The pulse was good but quick. At the moment the skin incision was made, the pulse suddenly ceased both at the wrist and at the neck, and remained absent for (?) four or five seconds. No loss of colour. Pulse resumed its

previous character. Some movement of patient, showing he was not deeply anæsthetised. Attempted to secure a better and more profound anæsthesia, but respiration tended to become feeble and face pale. No further trouble during rest of operation. This patient died some weeks later, and at the autopsy a large mediastinal (sarcomatous) tumour was discovered. This had probably caused the respiratory difficulties in the administration.

Whilst it must be admitted in this case that the patient was imperfectly anæsthetised, it does not follow, as we have seen, that the cardiac inhibition would not have arisen had the anæsthesia been deeper. The operator understood that the patient was ready for operation; whereas, owing to the embarrassed respiration, it had been found impracticable to arrive at tranquil anæsthesia in the usual time. It is probable that had the patient been under chloroform a more marked depression of circulation might have resulted.

The two following cases, which present points of great similarity, are of considerable interest in the present connection:—

Illustrative Case, No. 49.—The patient was a gentleman of about 35 years of age; of average build; in good general health; and not markedly nervous. He was the subject of a sarcomatous tumour of the soft palate. Chloroform was administered by means of Junker's inhaler. Anæsthesia was produced in from 8 to 10 minutes, and was characterised by muscular flaccidity, abolition of lid-reflex, and slight stertor. There were to be two stages in the operation—the first of which consisted in placing a temporary ligature round the carotid artery in the neck; the second in removing the growth of the palate. The skin incision was unattended by movement or other phenomena. Whilst the artery was being exposed the pulse became extremely feeble, the face pale, the respiration shallow, and the operator had some difficulty in recognising the vessel by reason of its diminution in size. The head was lowered and the legs raised. After three or four compressions of the chest the pulse gradually improved, and rigidity and lid-reflex reappeared. I then had recourse to ether for the remainder of the operation, which was successfully performed under this anæsthetic.

The next day, whilst the wound over the carotid was being examined without an anæsthetic, the patient's face suddenly became pale, the artery contracted as on the previous occasion, the eyes turned up, the muscles of the jaw twitched, and for a few seconds the patient was unconscious.

I anæsthetised this patient two years later, and gave him ether for the removal of a very small recurrent nodule. No difficulty occurred. It is fair, however, to add that no ligature was this time placed round the carotid.

I anæsthetised this patient for the third time, just three years after

the last administration. Another recurrent nodule had to be removed. I used the A.C.E.-ether-chloroform sequence, and secured a deep ether anæsthesia for the commencement and first stages of the operation. No abnormal symptoms were noted under ether; but during the subsequent chloroformisation, whilst the palate was being held, and a further portion of the growth excised, the pulse became very slow for three or four beats and for 20-30 seconds could not be felt. The respiration was deep and regular all the time. The colour was perhaps a trifle paler. The anæsthetic was withheld, and the pulse gradually returned. Though the patient was well under chloroform at the time the pulse vanished, he was not too deeply anæsthetised, for he began to show signs of recovery half a minute after the anæsthetic had been discontinued.

Illustrative Case, No. 50.—M., æt. 60. Healthy and muscular. Florid cheeks. Iron-grey beard. Had his tongue removed some months ago. Now has epitheliomatous glands of neck requiring removal. Heart-sounds good; not nervous. Chloroform administered on Skinner's mask. Drop-bottle. No struggling. Some temporary respiratory difficulty before deeply under, easily removed by pushing jaw well forwards. Fully anæsthetised in 5-6 mins. No movement with skin incision. The signs of anæsthesia were: Regular, softly snoring breathing: no corneal reflex: fixed eyeballs: pupils $3\frac{1}{2}$ mm.: good colour. As this pupil was a trifle larger than the ordinary chloroform pupil, I instructed the student who was administering the chloroform to somewhat lessen the amount of anæsthetic. This brought the pupil to $2\frac{1}{2}$ mm. in about half a minute. Other signs as before. A few minutes later, during the manipulations of the surgeon for the removal of the glands (which were intimately connected with the carotid, jugular, vagus, and phrenic), the patient became pale, and his jaw muscles flaccid. In a few seconds from this his breathing became irregular and shallow. No sound of obstruction. I assisted respiration by pressing with each expiratory effort upon the lower part of thorax, and with my finger in mouth kept stump of tongue from pharynx. The pulse, which had not been observed before, was barely perceptible and slow. (It had probably ceased altogether when the pallor came on.) Lid-reflex now returned, and some moaning. Carotid and jugular both ligatured and glands completely and successfully removed. The operation was never suspended, as no further remedy besides chest-compression was necessary. A comparatively light anæsthesia was kept up for the rest of operation. Any attempt to abolish lid-reflex was at once followed by feeble breathing. The colour and pulse improved after the chest-compression; but patient remained pale, and with rather slow and weak but regular pulse till end of operation. Administration lasted 50 minutes. 14 dr. of chloroform used.

The patient referred to in Case 49 was apparently specially susceptible to reflex cardiac inhibition. During the second operation, in which ether was employed, and during the first part of the third operation, which was also conducted under

this anæsthetic, no surgical shock occurred. But in the first operation, and in the latter part of the third operation, on both of which occasions chloroform was being used, reflex circulatory depression ensued. It is interesting, too, that a similar condition was noted in the absence of anæsthesia. In this case, as in many others, the stimulation produced by ether seems to have prevented the inhibitory effects of the surgical procedure.

In the following case the reflex cardiac inhibition occurred during an abdominal operation :—

Illustrative Case, No. 51.—F., æt. 42. Good colour. Rather grey. General condition good. Operation for gastric ulcer (abdominal section). Administration lasted about 70 minutes. Chloroform, Skinner's mask. No difficulty in induction. No reflex movement with incision. First part of operation consisted in pulling down stomach and plugging several large sponges into abdominal cavity. During this the lips became pale, the pulse small and slow, but the breathing was unaffected. (No corneal reflex present.) Difficult to say whether circulatory symptoms due to chloroform, to operation, or to both factors. No chloroform given for several minutes, during which there was no corneal reflex. Pulse and colour gradually improved, but by this time the dragging on stomach and insertion of sponges had ceased and the stomach had been opened. No further trouble for next 40 minutes. At end of this time, *when I was perfectly sure the patient was not too deeply under chloroform, and not too lightly*, it became necessary to remove sponges, and the patient again displayed similar symptoms to those previously noted. Clearly a reflex effect.

Reflex circulatory disturbances are very common during abdominal operations, *e.g.* ovariotomy, resection of intestine, etc. I have also met with symptoms of cardiac inhibition in cases of vaginal hysterectomy, the pulse becoming slow, feeble, irregular or intermittent during traction upon the uterus. I have invariably found that a change from chloroform to A.C.E., or from A.C.E. to ether, has corrected the condition.

The most profound shock that I ever witnessed during anæsthesia came about as the immediate result of air entering a vein. The following are the notes of the case :—

Illustrative Case, No. 52.—F., 14. Florid and fairly well-nourished. Removal of cervical glands. "Gas and ether" followed by chloroform. Whilst the operator was working in the supra-clavicular region, a small quantity of air was heard to enter a vein. This was followed by rapid pulse and some pallor. A minute or two later, whilst I was carefully feeling the superior coronary artery and watching the

patient, who was well under, but not too deeply under chloroform, there was a very distinct sound as of a considerable quantity of air entering a vein. The pulse suddenly vanished at the superior coronary and radial arteries; the face became deadly pale; the lids separated; the eyes became glassy, and the breathing barely perceptible. There were, in fact, all the appearances of death. I immediately lowered the head and raised the legs, and as the chest walls were remarkably elastic and yielding, and the abdomen relaxed, I was able, with my hands, to encircle the heart to such an extent that rhythmic compression of that organ became possible. The intermittent squeezing movements thus brought to bear also had the effect of forcing air in and out of the chest. At the end of three or four minutes signs of returning animation began to appear, and with the assistance of other restorative measures (strychnine, brandy enema, warmth, etc.) the patient recovered.

It is, I think, highly probable that in the above case the patient's life was saved by cardiac compression.

(iv.) **The Act of Vomiting.**—When vomiting leads to dangerous or fatal symptoms, it generally does so by reason of the interference with respiration which is a natural and necessary accompaniment of the act of emesis. Vomited matter may, as we have seen, readily pass into the larynx and trachea unless care be taken (p. 454). Or the suspension of breathing dependent upon the temporary laryngeal closure which takes place during vomiting may, in a feeble subject or in one whose heart is dilated or otherwise diseased, be rapidly followed by syncope, especially under chloroform (p. 348). But, apart from these respiratory embarrassments, the circulation may show signs of depression when vomiting is imminent, and this is particularly the case in light chloroformisation. The usual treatment when the pulse becomes feeble from impending vomiting is to increase the depth of anæsthesia; but in many cases it is impossible to ward off the *contretemps* by this plan, and the vomiting must be allowed to take its course. Whether there is ever any real danger in this form of circulatory depression—apart from the danger of suspended breathing—is questionable.

PART V

THE CONDITION OF THE PATIENT AFTER THE ADMINISTRATION

CHAPTER XIX

THE AFTER-CONDITION OF THE PATIENT

WE have seen, in considering the after-effects of each anæsthetic, that, when the administration is discontinued and fresh air admitted to the lungs, a kind of **retrogression** in the patient's symptoms commences. A true retrogression is rarely if ever observed—that is to say, a patient rarely if ever displays, in reverse order, precisely the same symptoms which occurred whilst he was passing under the influence of the anæsthetic. Speaking generally, we may say that, when the anæsthetic is withdrawn from a deeply-anæsthetised patient, the first thing usually observed is that the breathing grows quieter, and should stertor have been present, it becomes less pronounced. The next sign of recovery is usually the reappearance of the lid-reflex. Deglutition movements sometimes occur first. If the patient be left undisturbed, the pupil generally grows smaller; but dilatation may occur, more especially if the patient be disturbed, or the operation be still in progress. Dilatation may also be met with prior to vomiting. The globes now commence to move from their fixed positions. The breathing becomes intermittently obstructed, from the temporary laryngeal closure incidental to swallowing. Expiratory phonation and inspiratory crowing are sometimes heard. Coughing, retching, or actual vomiting may follow.

Recovery from anæsthesia takes place with a degree of rapidity which is roughly proportionate to the previous duration of the narcosis and to the quantity of the anæsthetic which has been inhaled. Other factors necessarily come into play. Patients with good respiratory action, a brisk circula-

tion, and a free air-way more quickly eliminate the anæsthetic than patients differently circumstanced. One test of a proper anæsthesia having been maintained is that the patient should soon commence to show signs of recovery. If he remain with an insensitive conjunctiva, and other evidences of deep anæsthesia, for some time after the administration, we may be pretty certain that an unnecessarily large dose of the anæsthetic has been given.

I find it an excellent practice, when circumstances permit, to **turn the patient well upon his side** immediately after a surgical operation, *i.e.* whilst he is still under the anæsthetic. This is the posture which Dr. Bowles[1] so strongly recommends in apoplectic seizures. Stertor at once ceases; the tongue gravitates to the side of the mouth; a free air-way is established; mucus and saliva are not swallowed; coughing is prevented; and should vomiting occur, any vomited matter will readily find an escape without interfering with breathing. If the patient's head be allowed to remain in the mid-line, and more especially if his chin be permitted to rest more or less upon his sternum, breathing cannot take place freely, and recovery will therefore be tardy and unsatisfactory.

If the patient has been in the sitting posture, as for a nasal or oral operation, he should be bent well forwards in the chair directly the operation is over, in order to facilitate the escape of blood from the mouth. He should then be placed laterally till recovery ensues.

It is important that **the administrator should stay by his patient** till distinct signs of recovery have manifested themselves. As a general rule, he should remain till some semi-voluntary action takes place, till vomiting has occurred, or till moaning sounds are made. Temporarily-obstructed breathing is common whilst patients, and more especially certain types of patients, are emerging from anæsthesia. It is hence necessary for the administrator to conduct his patient safely through the stage of retching; to push the jaw forwards; and to clear the mouth if occasion should require. Several deaths have occurred in consequence of the neglect of these precautions.

[1] *Stertor and Apoplexy.*

It is not advisable to administer an opiate after an operation till the patient has shown distinct signs of recovery; and this particularly applies to all cases in which any respiratory embarrassment is present.

Pallor and feebleness of pulse coming on after the administration are usually connected with vomiting. They may, however, depend upon other causes, *e.g.* the patient's general condition, the operation, etc. Moreover, we must remember that both ether and chloroform, and more especially the former, act as stimulants to feeble subjects; and that when the stimulant has been removed the circulation will inevitably flag to a greater or less degree. We must not lose sight of this fact in dealing with very exhausted subjects. In critical cases care should be taken to keep the head low and the patient very warm. Hot-water bottles and blankets should be applied; free respiration maintained; the lips rubbed with brandy and water; or an enema of brandy and beef-tea given. Hot-water bottles should always be enveloped in thick blankets, otherwise there will be a risk of inflicting injury to the skin of the still unconscious patient.

After the use of ether or chloroform for a surgical operation, no **nourishment** should be given by the mouth for about four hours, and if at the expiration of this period the patient be disinclined for food, another hour or even longer may be allowed to elapse. Some clear soup or broth may then be given. Properly made beef-tea, to which a small quantity of a reliable meat extract has been added, will be found to answer well. Some patients prefer solid Brand's Essence to any liquid nourishment. Soda-water with milk is sometimes preferred to soup or beef-tea. After short administrations some tea or coffee with dry toast may be permitted.

As the prevention and treatment of **nausea, retching, and vomiting** are matters of considerable importance, not only to the patient but to the surgeon, a few remarks, in addition to those which have already been made in previous pages, concerning the causation of these unpleasant sequelæ may not be out of place. Unfortunately our knowledge is very scanty—far scantier than it should be upon such a subject.

In the first place, it is hardly necessary to point out that the presence of food, etc., within the stomach during the administration is the most frequent cause of after-sickness. When the diet has been properly regulated, in accordance with the rules laid down on p. 186, after-vomiting is exceptional. When solids or liquids are present in the stomach during the administration, not only may the administrator have difficulty in obtaining a proper and quiet anæsthesia, but after-sickness will probably be troublesome. As a curious and interesting fact, however, I may say that I have met with one or two cases in which vomiting after ether was conspicuously absent, even though the patients had quite recently taken solid food. Such cases are very exceptional. As is well known, patients operated upon in the early morning, when the stomach is quite empty, are less prone to after-vomiting than those operated upon later in the day. I have repeatedly noticed that patients anæsthetised at 8 A.M. are very rarely attacked by nausea and retching afterwards—a fact which may probably be explained by supposing that tea, coffee, etc., which may be considered necessary before operations fixed for 9 A.M. or later, have not been given. When much blood has passed into the stomach during the operation, vomiting will almost certainly follow: and the same is more or less true with regard to mucus and saliva.

Secondly, as to the anæsthetic itself, we have seen (p. 234) that of all the anæsthetics nitrous oxide is least likely to be followed by vomiting, but there are certain highly exceptional cases in which even this anæsthetic cannot be inhaled without nausea and retching occurring. Moreover, the longer the inhalation, the greater will be the tendency to vomit—hence the greater liability to this symptom when nitrous oxide is inhaled with oxygen. With regard to ether and chloroform, we may say that the administration of the former is more often followed by transient retching than the administration of the latter. But, as has been pointed out, severe, protracted, and dangerous vomiting is more common after chloroform.

Thirdly, some patients are far more prone to these after-

effects than others. Rosy-cheeked children, young women of good colour and full lips, and flabby-looking individuals with an unhealthy and dusky appearance are much more liable to after-vomiting than others. Such patients nearly always secrete large quantities of mucus and saliva. Thin, spare, and sallow patients, those who have become anæmic from exhausting disease, as well as aged persons, are not often sick after anæsthetics. Patients of "bilious" habit frequently suffer a good deal after ether or chloroform—a fact recognised by Snow.[1] The administration of an appropriate purgative (p. 188) is said to diminish the chances of after-sickness.[2]

Fourthly, the nature of the operation may have its influences. Patients who have undergone operations in which the intestines have been freely manipulated are said by some to be specially liable to after-vomiting. I am also informed by one of our leading obstetric physicians that the operation of oöphorectomy specially predisposes to after-sickness of varying degrees in different cases. Dr. Sheppard states in his notes that he found vomiting to be rare after mouth and jaw operations; and Mr. Rigden (footnote, p. 305) makes the same observation.

Fifthly, the kind of anæsthetic employed must be considered. Although it is difficult to speak positively upon the point, I believe that pure ethylic ether is less frequently followed by nausea and vomiting than the so-called "Pure Methylated" ether; and it is possible that certain kinds of chloroform may be similarly superior to others in this respect.

Lastly, jolting the patient about during recovery from deep anæsthesia will often induce vomiting. It is important, therefore, that the patient should, whenever circumstances permit, be left undisturbed for some considerable time after the administration has been concluded. The custom of moving patients from the operating-table to the bed immediately after the operation is open to the objection that it often leads to

[1] *Op. cit.*

[2] I am told by a head-nurse at one of the surgical homes that this is an important point in the avoidance of vomiting.

vomiting. I have frequently known vomiting to be set up by simply moving the bed back to its position just after the operation.

If, then, we wish to avoid after-vomiting, an appropriate laxative or purgative must be given; the diet carefully regulated; a deep anæsthesia with the purest anæsthetic maintained; the head kept turned well to one side for the escape of mucus and saliva; and the patient placed upon his side directly the operation is over.

But **if nausea and vomiting arise, and prove distressing to the patient,** an endeavour must be made to relieve them. It is best, in the first instance, to give about five or six ounces of hot water to drink. Small pieces of ice were formerly advocated, but hot water seems more efficacious. I have frequently known a draught of hot water to immediately and finally arrest distressing retching. Should it not do so, some strong hot coffee without milk or sugar may be next tried.[1] I have notes of a case in which this treatment allayed vomiting which had lasted for twenty-four hours. When it does not relieve, I have known 10-15 grs. of bicarbonate of soda in very hot water to answer well. I have also notes of a case in which obstinate after-sickness was immediately stopped by champagne; and a case has been reported to me by a surgeon, in which obstinate nausea and retching after chloroform yielded to small doses of oxalate of cerium, after other remedies had failed. Kappeler recommends the application of an ice-bag to the epigastrium for after-sickness; but I have had no experience of this remedy. The inhalation of vinegar is said to be of use in controlling vomiting after chloroform.

Lenevitch[2] advises washing out the stomach with lukewarm alkaline solutions in severe after-vomiting; and Blumfeld,[3] who employs plain water for the purpose, speaks favourably of this line of treatment.

When there is a neurotic element in the vomiting following anæsthesia, much benefit may be derived from the use of

[1] Dr. Buxton (*Anæsthetics*) speaks highly of the addition of bicarbonate of soda to coffee.

[2] *Annual Univ. Med. Sci.*, 1892, p. 13.

[3] *Lancet*, 23rd September 1899, p. 833.

an enema of bromide of potassium (about 20 grs. to a couple of ounces of water).

I find that the disagreeable taste left in the mouth after the inhalation of ether is best treated by giving the patient very thin slices of lemon with which to moisten his lips from time to time.

Incautious ventilation should be avoided, owing to the risk which would otherwise result of giving the patient bronchitis, or even pneumonia. The room should be kept as quiet and dark as possible, in order to encourage natural sleep.

The special after-effects of each anæsthetic have been considered in Part III. Hysterical and other forms of excitement are referred to on pp. 235, 309, and 367; bronchitis, pneumonia, and pulmonary œdema on pp. 306 and 367; albuminuria, nephritis, and glycosuria on pp. 235, 308, and 367; hemiplegia and aphasia on pp. 235 and 310; choreiform movements on p. 309; and insanity on pp. 235, 309, and 367.

The occurrence of bronchial or pulmonary symptoms after anæsthetisation may, as we have seen, be dependent upon a foreign body, such as an extracted tooth, having passed into the trachea or bronchi. Several cases of this kind have been recorded. In some, recovery has taken place on the expulsion or removal by operation of the foreign body; whilst in others fatal results have followed.[1]

Finally, there may be met with, after all anæsthetics, certain paralytic conditions dependent upon injuries to peripheral nerves, from the adoption of certain postures. Thus, by dragging the arms over the head, Erb's palsy (paralysis of the deltoid, biceps, brachialis anticus, and supinator longus) or some similar condition may result, the nerve-trunks supplying the paralysed districts having been compressed between the clavicle and the first rib or stretched over the head of the humerus.[2] Again, the musculo-spiral or the ulnar nerve may become paralysed either by the trunk weight compressing

[1] This point has already been discussed (p. 460). See also *Lancet*, 15th December 1900, p. 1729, in which a case is quoted which exemplifies the difficulty in diagnosis which may sometimes be experienced.

[2] See an interesting article by Mr. Turney in the *Clin. Journ.*, 12th July 1899. See also *Lancet*, 3rd June 1899, p. 1508.

the nerve or by the arm resting against the edge of the operating-table. Or, lastly, by placing the patient in the lithotomy posture, nerve-trunks may be compressed, with results similar to those just described. As a general rule, all such paralyses are of a transient character, although one or two cases have been recorded in which more or less permanent effects have resulted.

GENERAL INDEX

INDEX OF AUTHORS QUOTED

THE END

Printed by R. & R. Clark, Limited, *Edinburgh*

DATE DUE

201-6503

Printed in USA